1991

Stratigraphy and sedimentology of the Upper Cretaceous (Santonian) Guinda Formation, Sacramento Valley, California

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Order Number 1345820

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San Jose State University, 1991

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STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER CRETACEOUS (SANTONIAN) GUINDA FORMATION, SACRAMENTO VALLEY, CALIFORNIA

A Thesis

Presented to

The Faculty of the Department of Geology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By

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August, 1991

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ACKNOWLEDGMENTS

A scientifically sound thesis is rarely the result of only one person's efforts. Throughout this project, many people both directly and indirectly contributed to its success and completion.

Foremost, my sincere gratitude is extended to Cal Stevens, who helped make this thesis the rewarding experience I had hoped it would be. Special thanks are also due the other members of my committee, Dave Andersen and Scott Creely.

Many others throughout this project generously shared with me their time and expertise. Donald Moore, my classmate, occasional field partner, friend, and confidant, helped put the geologic complexities of the Sacramento basin into perspective. Roy Fulwider at UNOCAL helped with microfossil identifications, age assignments, and paleobathymetry. Russ Robinson, at the California Well Sample Repository, and Ed Stinemeyer, consulting geologist, graciously helped with my core examinations.

To those people who both directly and indirectly helped me throughout this project, I express my genuine appreciation. This includes Greg Barats, Keith Berry, Keith Green, William Hughes, Douglas Imperato, David Klise, Tor Nilsen, Vince Ramirez, and all former workers of Sacramento basin geology upon whose work I relied.

I also would like to acknowledge the landowners and corporations that allowed me access to their property for examination of outcrops, including American Telephone and Telegraph (ATT), Eugene Brazelton, John Hayes, Donald Lederer, Anita McMillon, Luke Reamer, Bob Rogers, and Donald Tompkins. This project couldn't have been done without their assistance.

A very warm thanks goes to my parents, Ray and Jean, for all their support and for instilling at a very early age my yearning for scientific inquiry and understanding. I also want to extend a very appreciative thanks to my brother, Jeff, who provided critical review and editing of portions of the manuscript, as well as to my sister, Melody, who helped in ways she will never fully realize.

Lastly, I would like to thank my wife and very best friend, Joanie. Without her and the sacrifices she was willing to make, I never would have had the stimulus to complete this thesis in a timely fashion, nor the drive to see this project through to its completion. With love, this thesis is dedicated to her.

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ABSTRACT

The Guinda Formation, part of the Great Valley Group, is a very complex Upper Cretaceous sedimentary unit that crops out along the eastern margin of the northern Coast Ranges of California and underlies the western half of the Sacramento basin. This unit averages about 200 m (700 ft) in thickness, although it approaches 300 m (1000 ft) in thickness near the western margin of the Sacramento basin. Near the eastern margin of the Sacramento basin, the Guinda Formation thins and eventually onlaps the Sierra Nevada basement or grades into the shallow-marine rocks of the Chico Formation.

Data gathered primarily from outcrops indicate that the Guinda Formation was deposited as a mixed-sediment deep-sea fan turbidite system. The Guinda Formation is interpreted to represent a deep-sea fan system because this unit includes abundant sedimentary features characteristically produced by sediment-gravity flows, including repetitive interbedding of sandstone and shale, sole markings, graded bedding, and the presence of Bouma sequences. The Guinda fans, which were deposited on a basin plain, were fed by sediment that passed through the deltaic system on the Chico shelf. Paleocurrent data suggest that, as the sediment prograded westward across the basin from its source in the Sierra Nevada, much of the

sediment was funneled southward along the plunging axis of the actively evolving Great Valley forearc basin.

Microfossils from the Guinda Formation and adjacent basin-wide shale units confirm that the Guinda Formation is Santonian in age and falls within Goudkoff's G-1 foraminiferal zone. Deposition occurred in middle- to lower-bathyal environments above the calcium-carbonate compensation depth. Paleontologic and other data suggest that deposition of the Guinda fan system occurred over a relatively short period of time of less than 1 million years.

Sandstones of the Guinda Formation are compositionally immature to submature, matrix rich, medium grained, and moderately sorted; the grains are subangular to subrounded and have undergone significant mechanical and chemical compaction. Framework grains and pebble clasts typically are composed of a significant volcanic fraction, suggesting that the source area was volcanically active. The volcanism may have been related to the Cathedral Range intrusive event that was occurring in the Sierra Nevada while the Guinda Formation was being deposited.

Petrographic data do not preclude the possibility that some sediment was derived from the Klamath Mountains to the north, but the amount probably was not significant. Only minor compositional variations were noted in samples taken vertically and along strike, suggesting that the sediment was well mixed prior to its final deposition.

Where the Guinda Formation is in contact with the basement rocks along the Sierra Nevada, subsurface logs show that commonly it fills structural lows and is either absent or forms only a thin veneer over adjacent basement highs. This suggests that during deposition of the Guinda Formation the basement of the eastern Great Valley was tectonically active and was dominated by a series of upthrown and downthrown fault blocks.

Even though many units younger than the Guinda Formation produce prolific amounts of natural gas in the Sacramento basin, the Guinda Formation has remained largely unproductive. The reasons for the apparent lack of known hydrocarbons in this unit may be related to inadequate source rocks, scarce or leaked hydrocarbon traps, permeability barriers, or a lack of adequate testing.

INTRODUCTION

The Upper Cretaceous (Santonian) Guinda Formation is part of a very thick section of Upper Jurassic to Tertiary rocks deposited in the Sacramento basin of northern California. The Guinda Formation crops out along major stream cuts and well-exposed ridges in a narrow band located along the eastern margin of the northern Coast Ranges. The subsurface extent of the Guinda Formation is not well documented because in most places this unit is deeply buried and has not been an active drilling target by oil and gas companies.

The Sacramento basin, which is approximately 320 km (190 mi) long and up to 80 km (50 mi) wide, lies between the Coast Ranges to the west, the Sierra Nevada to the east, the Klamath Mountains to the northwest, and the Cascade Range to the northeast. Along with the San Joaquin Valley to the south, it forms the Great Valley, one of several physiographic provinces that compose California (fig. 1). By convention, a broad, buried anticlinal fold trending northeasterly across the valley, known as the Stockton arch or escarpment (Garrison, 1961), is considered to separate the San Joaquin Valley from the Sacramento Valley.

Structurally, the Sacramento basin is an elongated trough (fig. 2), trending north-northwesterly, with its

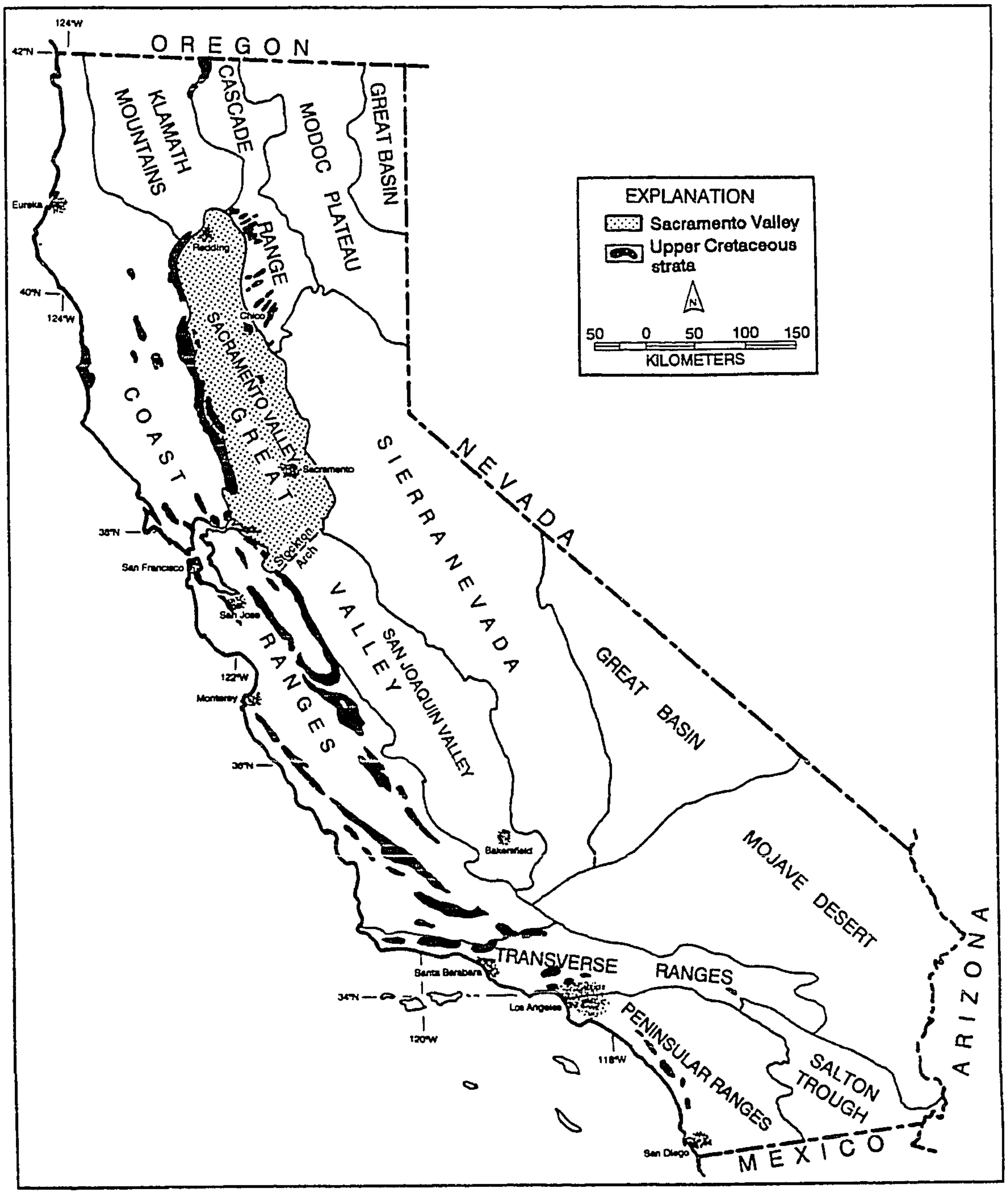


Figure 1. Location of Upper Cretaceous strata and the principal geologic provinces of California (outcrop locations from Jennings, 1977).

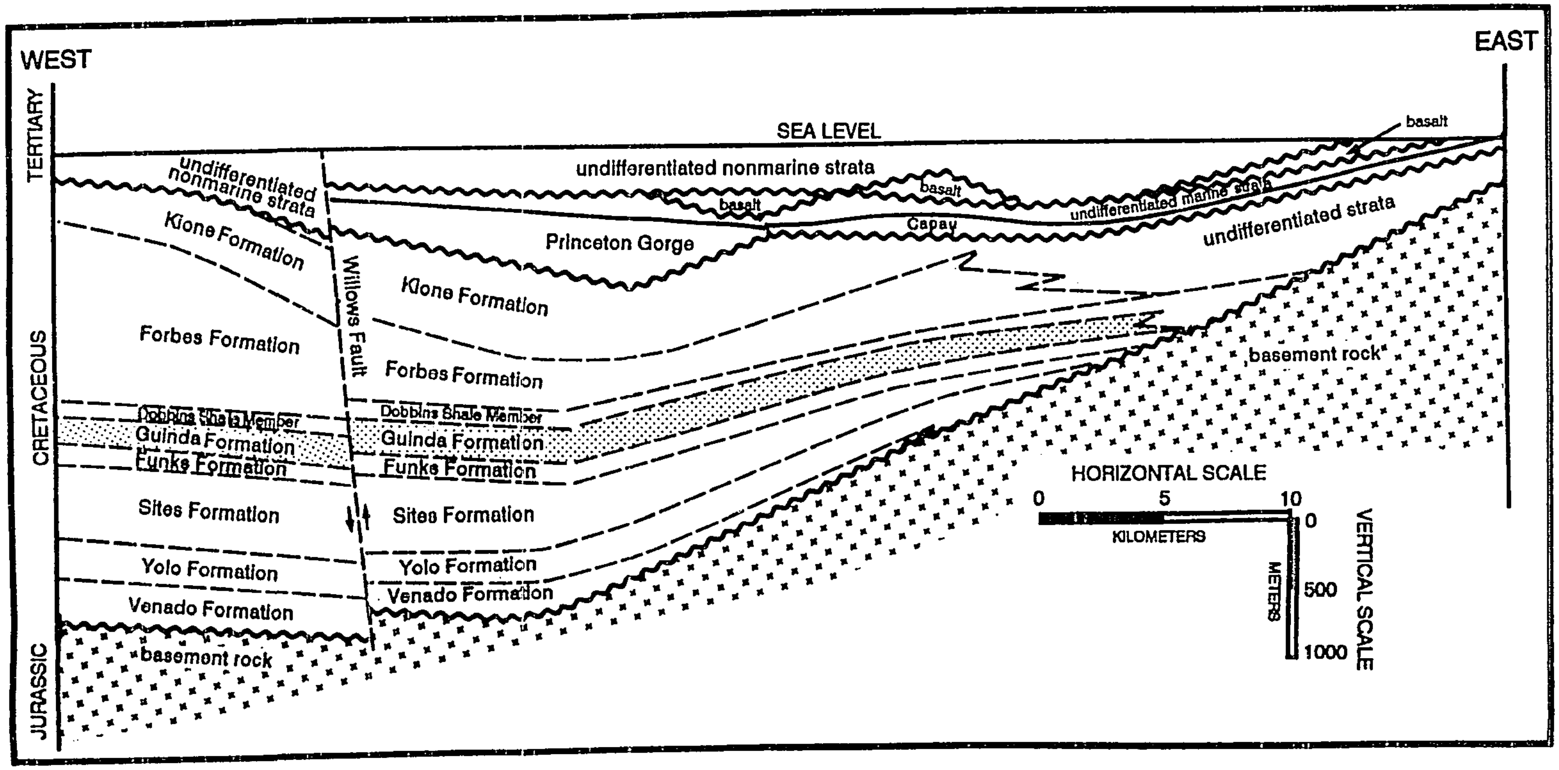


Figure 2. Generalized east-west cross section across the northern Sacramento basin, near the latitude of Willows, California, showing the structure and stratigraphy in this area (modified from California Division of Oil and Gas, 1982a).

axis eccentrically located near the western margin of the basin. During the Mesozoic, this basin had a pronounced southerly tilt, which resulted in a thickening of the sedimentary section in that direction (Ingersoll, 1976).

Strata of the Great Valley, of which the Guinda Formation is a part, commonly are referred to as the Great Valley Group (Ingersoll, 1982). This name will be adopted in this paper, although these rocks are perhaps more accurately called the Great Valley Supergroup (Article 29, North American Commission on Stratigraphic Nomenclature, 1983), which would encompass the interrelated Upper Jurassic Knoxville Group, the Lower Cretaceous Shasta Group, the Upper Cretaceous Chico Group, and the Paleocene Martinez Group.

Ingersoll (1976, 1978a) and Nilsen et al. (1986, 1990), among others, have presented strong evidence that the Guinda Formation and other sandstone-dominated units of the Great Valley Group represent deep-sea fans. Most diagnostic are the abundant sedimentary features characteristically produced by sediment-gravity flows that occur throughout these rocks. These include repetitive interbedding of sandstone and shale, sole markings, graded bedding, and the presence of Bouma sequences. Whereas it is possible for some of these features to occur in environments other than a deep-marine setting, their close association with a deep-marine faunal assemblage strongly suggests otherwise.

Purpose

The Great Valley forearc basin and several economically significant units of the Great Valley Group have been studied quite extensively; however, specific investigations on the Guinda Formation are virtually nonexistent. The lack of substantive data on units such as the Guinda Formation has resulted in "research gaps" in the geologic record of the Great Valley Group. The goal of this report is to develop a greater insight into the genesis, nature, and areal extent of the Guinda Formation than had been accomplished previously, to determine the source of sediment that was supplied to the Guinda Formation, and to interpret conditions that were prevalent in the Great Valley forearc basin during its deposition. The integration of several scientific disciplines into a coherent picture of basin evolution adds to a more thorough knowledge of deposition in the Great Valley forearc basin.

Scope of Investigation

An exhaustive search of the literature on the Great Valley Group and related subjects was conducted in the early phases of research. This work proved invaluable in bringing together what little work had been done on the

Guinda Formation and in understanding the geology of the Great Valley Group. To help define the lateral extent and best exposures of the Guinda Formation and to delineate access routes, information was gathered from existing geologic maps, reconnaissance trips, and interpretations from aerial photographs and orthophotoquads from the U.S. Geological Survey.

Several outcrop sections were selected and measured in detail. Paleocurrent data were collected and analyzed during measurement of each of the outcrop sections to develop a better understanding of the growth pattern of the Guinda deep-sea fan system. This work was augmented by examination of a diamond-drill core that penetrated the Guinda Formation in the vicinity of Putah Creek. This core proved valuable by showing petrographic and sedimentologic details that generally are not visible on weathered surfaces. In addition, examination of geophysical well-logs scattered throughout the Sacramento basin was useful in helping to establish the lateral extent of the Guinda Formation and in developing a depositional model of this unit.

Mineralogic analyses and point counts were conducted on petrographic thin sections taken from surface samples to evaluate the mineralogical variability of the framework grains both along strike and vertically through the formation. These data were augmented with a pebble count of one conglomerate.

Fine-grained outcrop samples were collected and processed for microfossils to help establish the paleobathymetry and age. Ages established from the examination of microfossils provided correlation with the foraminiferal zonation scheme originally developed by Goudkoff (1945).

Location of Study Area

The Guinda Formation is known in outcrop only along the western margin of the northern Coast Ranges. Outcrops extend from Black Butte Reservoir in the north to near Vacaville in the south (fig. 3), a distance of about 165 km (100 mi). The Guinda Formation also underlies large portions of the northern and central Sacramento basin.

Geography and Access

Physiographically, the Sacramento Valley consists largely of a low-lying and extensively alluviated terrain with elevations ranging from a few tens of meters to nearly 1000 m (3300 ft) above sea level along some of the ridges that parallel the western margin of the Sacramento Valley. Low-lying hills generally are covered with grass and thick brush; scattered oak trees prevail at the higher elevations. Native vegetation in the region includes chamise, manzanita, and buckthorn.

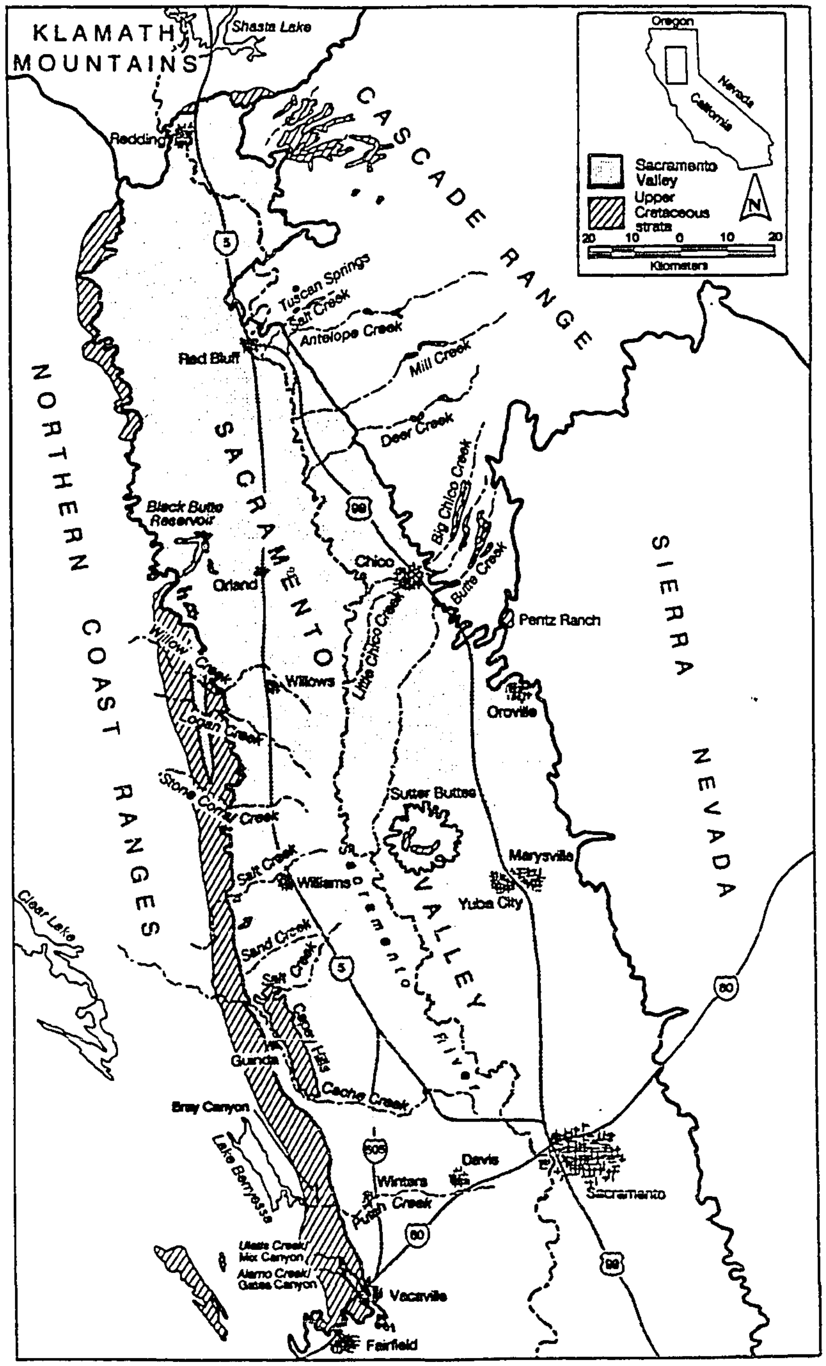


Figure 3. Generalized map of the Sacramento Valley showing the major cities, roads, streams and rivers, physiographic provinces, and the location of principal outcrops of Upper Cretaceous strata (outcrop locations from Jennings, 1977).

Weather in the Sacramento Valley is dominated by two seasons: a wet, cool winter and spring, and a very dry, hot summer and autumn. Coldest temperatures in the winter and spring rarely go below -5° C (20° F) and summer highs often exceed 35° C (95° F) for extended periods.

Whereas transportation routes in and around the valley are very good, access roads into the surrounding foothills generally are quite poor. Many of these roads are private and consist of unpaved jeep and truck trails used for maintaining livestock and gaining access to hunting areas. When wet, these roads can become nearly impassable, even to four-wheel-drive vehicles. Additionally, many access roads are gated and locked; hence, many of the better outcrop localities can be reached only by foot.

PREVIOUS WORK

The earliest published study concerning the strata that crop out along the margins of the Sacramento Valley was by Trask (1856), who described a collection of ammonites from the Chico Formation located along Big Chico Creek in the southeastern Cascade Range (fig. 3). Most early research that followed Trask's publication was by other fossil collectors (e.g., Gabb, 1864, 1867, 1869; Blake, 1858; White, 1885a, 1885b, 1889; Diller, 1894; Diller and Stanton, 1894; Anderson, 1902). Much of this early geologic work was summarized by Jenkins (1943), Matsumoto (1959), and Popenoe et al. (1960).

Lithostratigraphy

Following the early paleontologic studies, many nomenclatural schemes were developed to differentiate the various rock units in the Great Valley (Arnold and Anderson, 1910; Anderson and Pack, 1915; Durst, 1916; Smith, 1916). In the 1930's, Anderson (1932, 1933, 1938) published several detailed studies of the stratigraphy in this area and laid the foundation for a coherent stratigraphic classification scheme for the Great Valley.

Kirby (1935, 1941, 1942, 1943a, 1943b, 1943c) was the first to present a detailed lithostratigraphic subdivision of the Upper Cretaceous strata of the Great Valley, dividing the Chico Group into six formations: from oldest to youngest they are the Venado, Yolo, Sites, Funks, Guinda, and Forbes. His work was based primarily on field observations made along the eastern foothills of the northern and central Coast Ranges.

Many stratigraphic correlation charts of Upper Cretaceous Great Valley strata have been published since those of Kirby. They are included in the works of Goudkoff (1945), Cross (1954), Matsumoto (1960), Harding et al. (1960), Chuber (1961), Brooks (1962b), Lachenbruch et al. (1962), Sonneman and Switzer (1962), Ojakangas (1964), Edmondson (1967), Rich (1968), Bishop (1970), Berry (1974), Pessagno (1974), Drummond et al. (1976), Ingersoll (1976), Suppe (1979), California Division of Oil and Gas (1982b), Bishop and Davis (1984a, 1984b), Almgren (1986), Filewicz (1986), Bartow and Nilsen (1990), and Nilsen (1990). The development of various nomenclatural schemes for the Cretaceous strata of California and the problems that they created have been summarized by many workers including Jenkins (1943), Taliaferro (1943), Goudkoff (1945), Murphy (1956), Anderson (1958), Popenoe et al. (1960), Chuber (1961), Durham (1962), Bailey et al. (1964), Murphy et al. (1964), and Ingersoll (1979, 1990).

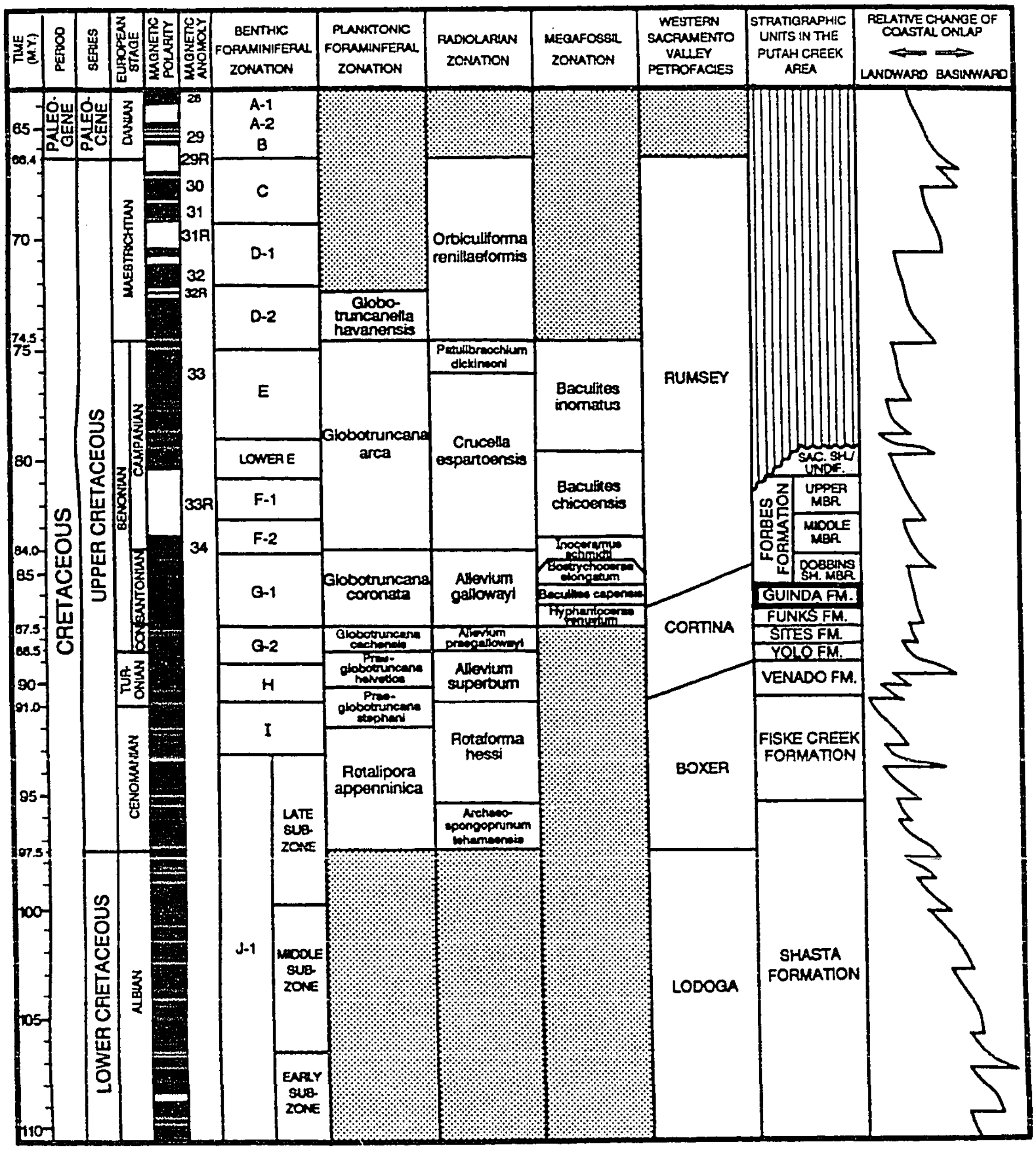
Even with the many stratigraphic classification schemes that have been published over the years, the formational names of Kirby (1943c) have proven useful, gained widespread acceptance, and are adopted for this report. The nomenclatural scheme for the Great Valley Group and paleontologic zones based on different fossil groups are shown in Figure 4.

Maps and Field Guides

Many maps and field trip guidebooks showing the distribution of Upper Cretaceous strata along the margins of the Sacramento Valley have been published over the years, including those of Kirby (1943a, 1943b, 1943c), May and Hewett (1948), Taylor (1955), Boyd (1956), Lawton, (1956), Garrison (1961, 1962a, 1962b), Lachenbruch et al. (1962), Olmsted and Davis (1962), Sonneman and Switzer (1962), Brown (1964), Smith (1964), Ojakangas (1964), Emerson (1966), Rich (1968, 1971), Swe (1968), Griscom (1973), Chapman et al. (1975), Rich and Ingersoll (1975), Sims and Frizzel (1976), Dickinson and Rich, 1978; Jennings (1977), Suppe (1979), Graham and Ingersoll (1981), Ingersoll and Graham (1981a, 1981b), Roberts et al. (1981), Wagner and Bortugno (1982), Oliver et al. (1985), Haggart (1986b), Chapman and Bishop (1988), Manson (1989, 1990), Bartow and Nilsen (1990), and Nilsen and Imperato (1990). Among these references, however, the Guinda Formation commonly has been combined with other Cretaceous units.

The geologic maps of Emerson and Roberts (1962) in the

Figure 4. Chart showing Cretaceous and early Paleocene time and time-rock divisions (from Berggren et al., 1985; Kent and Gradstein, 1985); magnetostratigraphy (from Haq et al., 1987; Verosub et al., 1989), biostratigraphy showing benthic foraminiferal zonations (from Goudkoff, 1945; Berry, 1974; Almgren, 1986), planktonic foraminiferal zonations (from Douglas, 1969; Trosper, 1985), radiolarian zonations (from Pessagno, 1976), and megafossil zonations (from Haggart and Ward, 1984; Verosub et al., 1989); and sequence stratigraphy showing western Sacramento Valley petrofacies (from Ingersoll, 1983), stratigraphic units in the Putah Creek area (from Kirby, 1943c; Bishop and Davis, 1984b), and eustatic changes in sea level (from Vail and Mitchum, 1979; Haq et al., 1987) (abbreviations: Con.=Coniacian; Fm.= Formation; Mbr.=Member; Sh.=Shale; Undif.= Undifferentiated).


TIME (M.Y.)
PERIOD
SERIES
EUROPEAN STAGE
MAGNETIC POLARITY
MAGNETIC ANOMOLY
BENTHIC FORAMINIFERAL ZONATION
PLANKTONIC FORAMINFERAL ZONATION
RADIOLARIAN ZONATION
MEGAFOSSIL ZONATION
WESTERN SACRAMENTO VALLEY PETROFACIES
STRATIGRAPHIC UNITS IN THE PUTAH CREEK AREA
RELATIVE CHANGE OF COASTAL ONLAP
LANDWARD BASINWARD
65
66.4
70
74.5
75
80
84.0
85
87.5
88.5
90
91.0
95
97.5
100
105
110
PALEO-GENE
CRETACEOUS
PALEO-CENE
UPPER CRETACEOUS
LOWER CRETACEOUS
DANIAN
MAESTRICHTIAN
CAMPANIAN
SENONIAN
SANTONIAN
CONIACIAN
TUR-ONIAN
CENOMANIAN
ALBIAN
28
29
29R
30
31
31R
32
32R
33
33R
34
A-1
A-2
B
C
D-1
D-2
E
LOWER E
F-1
F-2
G-1
G-2
H
I
J-1
LATE SUB-ZONE
MIDDLE SUB-ZONE
EARLY SUB-ZONE
Globo-truncanella havanensis
Globotruncana arca
Globotruncana coronata
Globotruncana cachensis
Prae-globotruncana helvetica
Prae-globotruncana stephani
Rotalipora appenninica
Orbiculiforma renillaeformis
Patulibracchium dickinsoni
Crucella espartoensis
Alievium gallowayi
Alievium praegallowayi
Alievium superbum
Rotaforma hessi
Archaeo-spongoprunum tehamaensis
Baculites inornatus
Baculites chicoensis
Inoceramus schmidti
Bostrychoceras elongatum
Baculites capensis
Hyphantoceras venustum
RUMSEY
CORTINA
BOXER
LODOGA
SAC. SH./ UNDIF.
FORBES FORMATION
UPPER MBR.
MIDDLE MBR.
DOBBINS SH. MBR.
GUINDA FM.
FUNKS FM.
SITES FM.
YOLO FM.
VENADO FM.
FISKE CREEK FORMATION
SHASTA FORMATION

Putah Creek area; Brooks et al. (1962a), Court (1966), Wagner and Saucedo (1984), and Ramirez et al. (1986) in the Capay Hills (locally called the "Rumsey Hills") area; and Chuber (1961) in the Elk Creek-Fruto area proved particularly useful in mapping the Guinda Formation. The maps by Brooks et al. (1962a) and Emerson and Roberts (1962), rather than representing new work, were based on a compilation of existing published and unpublished data. Some maps showing the location of the Guinda Formation and associated strata of the Great Valley Group (e.g., those of Sims et al., 1973; Stinemeyer, 1979) differ significantly from the other published data.

Petrography

Bailey and Irwin (1959) were the first to recognize petrographic differences between sandstone bodies in the Sacramento Valley. Several years later, Dickinson and Rich (1972) suggested that these rocks could be subdivided and correlated by petrographic means. They believed that the petrofacies of the Great Valley Group generally correspond to time-stratigraphic intervals and intrusive events in the Sierra Nevada. Ingersoll (1976, 1981, 1982) added many details to this earlier work and suggested that the petrofacies could be correlated with European stages. Short and Ingersoll (1990a, 1990b) indicated that strata in the extreme northern part of the Great Valley reflect a dominantly Klamath Mountains source rather than a Sierra Nevada source.

Other petrographic studies of the Great Valley Group include those by Rozelle (1962), Schilling (1962), Tamesis (1966), Gilbert and Dickinson (1970), Swe and Dickinson (1970), Mansfield (1971, 1972), Ingersoll et al. (1977), Ingersoll and Dickinson (1981), Bertucci (1983), Bertucci and Ingersoll (1983), and Mertz and Nilsen (1990). All of these added greatly to our understanding of the petrographic character of the Great Valley Group.

Biostratigraphy

Foraminifera

Goudkoff (1936, 1937) was the first to attempt a biostratigraphic zonation of Upper Cretaceous strata of the Great Valley. Additional research by Goudkoff (1942, 1945) helped refine his original foraminiferal zonation scheme.

Bandy (1951) and Loeblich (1958) showed that many of Goudkoff's zones could be equated to European stages. Unfortunately, in developing the foraminiferal zonation scheme, Goudkoff focused on the stratigraphic distribution of benthic taxa, the lateral and stratigraphic distributions of which are closely tied to paleobathymetry, and he mostly excluded planktonic foraminifera (Trujillo, 1960; Graham and Clark, 1961; Edmondson, 1962). Almgren (1959, 1986) and Berry (1974) refined Goudkoff's foraminiferal zonation scheme using planktonic forms.

Recent research has firmly established that the Guinda Formation falls within Goudkoff's foraminiferal G-1 zone (e.g., Berry, 1974; Almgren, 1986). The G-1 zone has a large and varied fauna which is characterized by *Gaudryina pyramidata*, *Planularia tricarinella*, *Pleurostomella subnodosa*, *Pleurostomella greatvalleyensis*, and *Anomalina popenoei*. However, nearly all the benthic index species associated with the G-1 zone also are present in the F and lower E zones, so care must be taken to determine the stratigraphic position in any section (K.D. Berry, oral comm., 1989). Fortunately, planktonic species such as *Globotruncana pseudolinneana* and *Globotruncana globigeriniformis*, which have worldwide ranges that extend only to the top of the Santonian stage, also occur in the Guinda Formation. The Guinda Formation falls within the *Globotruncana coronata* planktonic foraminiferal zone of G-1 and the lowermost F-2 zone (fig. 4).

Radiolaria

Although radiolaria are far more abundant than other types of microfossils in the Great Valley Group, their importance for correlating strata has been fully appreciated only since the early 1970's. This research has been carried out primarily by Pessagno (1970, 1971a, 1971b, 1972a, 1972b, 1973, 1974, 1976), Pessagno et al. (1984), and Levy (1977). Other contributions have been made by Clark (1942) and by Campbell and Clark (1944).

Pessagno's (1976) radiolarian zonation for the Great Valley Group was based on outcrop samples that yielded 115 species, 36 of which were first described by Pessagno. Pessagno's zonation scheme approaches the degree of subdivision achieved by Goudkoff's zonation scheme, and, in most cases, it can be related to the foraminiferal zones.

Pessagno (1976) observed that radiolaria are not very common in the Guinda Formation, with most specimens occurring within isolated zones or specific beds.
He had only limited success finding radiolaria in the basal portions of the Guinda Formation along Putah Creek, east of Bray Canyon, and in the Capay Hills. Most of the radiolarians were recovered from calcareous concretions, but only a few specimens were identifiable due to their poor state of preservation. However, the presence of Orbiculiforma quadrata indicates that the lower part of the Guinda Formation in Bray Canyon is part of Pessagno's Alievium gallowayi zone, which is Santonian (Pessagno, 1976). He was also able to extract pyritized radiolaria (sample NSF 262) in an unspecified area along Sand Creek (fig. 3). Work by this author, however, indicates that the Guinda Formation is not present in the Sand Creek area, so it is doubtful that these specimens were recovered from the Guinda Formation.

The Guinda Formation is part of the Alievium gallowayi radiolarian zone of Pessagno (1976). The base of this zone is defined by the first appearance of Alievium gallowayi. Crucella espartoensis, Pseudoaulophacus floresensis, and Pseudoaulophacus colburni also make their first appearance just above the base of the Alievium gallowayi zone. The top of this zone is defined primarily by the last appearance of Archaeospongoprunum bipartitum and Orbiculiforma quadrata.

Nannofossils

Thierstein (1976) has done extensive work on the biostratigraphy of Mesozoic calcareous nannoplankton of California. Filewicz (1986) refined Thierstein's work while studying Santonian and Campanian nannofossils from the Forbes Formation located along Salt Creek in the Capay Hills. Because much of the work related to nannofossils has been done only in recent years, a basin-wide biostratigraphic zonation scheme has not yet attained the same level of refinement as those based on foraminifera and radiolarians.

Megafossils

Although almost all the early paleontological work in the Great Valley was based on analysis of megafossils, their paucity and common poor state of preservation make age determinations based on microfossils preferable. In recent years, however, there has been significant progress in developing an Upper Cretaceous Great Valley Group time zonation based on megafossils.

Matsumoto (1959, 1960) was the first to develop a megafossil zonation scheme for Cretaceous strata of the Sacramento Valley based on ammonites and inoceramid bivalves. His work was also significant because he reportedly collected megafossils from the Guinda Formation in the Capay Hills and along Putah Creek. However, the specimens from the Capay Hills are late Turonian, which suggests recovery from the underlying Sites Formation, and the Putah Creek samples were determined to be Campanian and therefore probably were collected from the unnamed middle member of the Forbes Formation (Pessagno, 1976).

Subsequent work of Kusnick (1981), Ward and Haggart (1981), and Haggart and Ward (1984) refined and enhanced the work of Matsumoto and showed that megafossils can be used as correlation tools in at least the upper portions of the Great Valley Group. Later, Haggart (1982, 1984), working with the biostratigraphy of the Chico Formation, revised Matsumoto's zonation.

Chuber (1961) located fragments of <u>Baculites chicoensis</u> in the Guinda Formation along the South Fork of Willow Creek (fig. 3). Outcrops at Black Butte Reservoir have yielded fragments of <u>Baculites</u> <u>elongatum</u> from the uppermost Guinda Formation and lower half of the overlying

Dobbins Shale Member of the Forbes Formation (Haggart and Ward, 1984). Haggart (1984) determined that the base of the Baculites chicoensis zone comes very close to approximating the Santonian-Campanian boundary in this area.

Megafossil biostratigraphic schemes by Jeletzky (1970) and Ward (1978) placed the Guinda Formation in the Bostrychocerase elongatum zone on the basis of molluscan assemblages; however, their supporting data are somewhat limited. Matsumoto (1959, 1960) placed the Guinda Formation in the Baculites capensis zone. This conclusion is supported by voluminous data collected by Haggart (1984) and Haggart and Ward (1984). The top of this zone is marked by the first appearance of the ammonites Submortoniceras chicoense and Baculites chicoensis and Inoceramus subundatus. This zone terminates with the disappearance of the mollusk Eupachydiscus haradai.

Magnetostratigraphy

Magnetostratigraphy has been very useful in correlating certain strata of the Great Valley Group. Ward et al. (1983) identified marine magnetic anomaly 33R at four sites, two on each side of the Sacramento Valley, thus providing correlation across the Great Valley. Based on the megafossils, they determined that the lower boundary of magnetic anomaly 33R is time-equivalent to the earliest

Campanian, and thus provided the first direct correlation of provincial biostratigraphic zones of the north Pacific with European stages. Their work confirms studies by Premoli Silva (1977) and Alvarez et al. (1977), who placed the boundary between the Santonian and Campanian immediately below the lower boundary of magnetic anomaly 33R. Additional study by Verosub et al. (1989) on the Chico Formation and the Forbes Formation substantiated the work of Ward et al. (1983).

Tectonics

Reed (1933) and Reed and Hollister (1936) published the first comprehensive interpretation of the Mesozoic and Cenozoic tectonics of California. Others have since made significant contributions in this field, including Bailey and Blake (1969), Dickinson (1974a, 1974b, 1976), Ingersoll (1978a, 1978b, 1983, 1988), Nilsen (1977a, 1977b, 1978a, 1990), Dickinson and Seely (1979), Ingersoll and Dickinson (1981), Jones et al. (1983), Suchecki (1984), Moxon (1990), and Ramirez (1990). General summaries of the tectonics of northern and central California have been presented by Howard (1979) and Nilsen (1986, 1991).

Recent tectonic studies concerning the physiographic provinces surrounding the Sacramento Valley portion of the Great Valley include those on the Franciscan Complex by

Bailey et al. (1964), Bailey and Blake (1969), Ernst (1970), Blake and Jones (1974, 1981, 1982), Blake (1984), and Howell (1985). Studies conducted on the tectonics of the northern Coast Ranges include those of Aalto (1982), Barbat (1971), Carlson (1984), and Nilsen (1987). Published studies of the tectonic framework of the Klamath Mountains and northern margin of the Sacramento basin include those of Davis (1969), Irwin (1981, 1985), Nilsen (1984), Haggart (1986a), and Miller (1989). Major contributions toward understanding the tectonic setting of the northern Sierra Nevada have been made by Bateman and Wahrhaftig (1966), Bateman (1967, 1969, 1981, 1983), Evernden and Kistler (1970), Bateman and Clark (1974), Schweickert and Cowan (1975), Schweickert (1981), and Frei et al. (1984).

Deposition by Sediment-gravity Flows

The sedimentologic processes that govern deep-water clastic systems, primarily turbidites, are important topics in helping to understand the stratigraphic development of the Great Valley Group. Early research in the 1950's and early 1960's focused mainly on the detailed analysis of small-scale structures in turbidites. Most notable during this period was the work of Bouma (1962), who proposed an idealized sequence of sedimentary textures and structures in a classical turbidite, designating five divisions, T_a -

T_e, that has since become widely accepted.

Middleton and Hampton (1973, 1976) and Lowe (1982), among others, recognized that various processes are responsible for different types of sediment-gravity flows. These workers showed that classification of submarine flows could be based on the nature of the flow's dominant sediment-support mechanism.

Mutti and Ricci Lucchi (1972, 1975) recognized that deep-marine sedimentary units in submarine fans could be assigned to seven facies (Facies A through G). This scheme is based chiefly on grain size, bed thickness, bed geometry, and sedimentary structures; thus it is largely descriptive.

One very important aspect of the Mutti and Ricci Lucchi classification scheme is that it can help identify the depositional environment of any particular sequence in terms of its position on a fan. In this scheme, submarine fans are divided into 12 facies associations including: upper slope, slope, submarine canyon, gully complex, inner-fan channel, middle-fan channel, crevasse-splay, levee, interchannel, outer-fan lobe, fan-fringe, and basin-plain. Ingersoll (1976) and Nelson and Nilsen (1984) have provided excellent summaries and examples of the facies and facies associations of Mutti and Ricchi Lucchi (1972, 1975).

REGIONAL FRAMEWORK

The Great Valley forearc basin dominated northern California during the Cretaceous (Ingersoll, 1976, 1983). This forearc basin formed following an episode of arc-continent collision in which a Late Triassic-Middle Jurassic subduction zone became plugged by accretion of an island arc (Schweickert and Cowan, 1975). The forearc basin was then created in response to subduction of the Farallon Plate beneath the North American plate (Nilsen, 1986).

The Great Valley forearc basin developed in the arc-trench gap between the Sierra Nevada magmatic arc to the east (Bateman, 1983) and the Franciscan subduction complex to the west (Aalto, 1982). Bounding the forearc basin to the north was the Klamath Mountains, which apparently represented a westward bulge in the post-Nevadan North American coastline (Short and Ingersoll, 1990b).

Ingersoll (1981) concluded that the Great Valley forearc basin widened through time as the locus of subduction migrated westward toward the downgoing oceanic slab, and the locus of magmatism migrated eastward through time (fig. 5). By the Late Cretaceous, the Sacramento basin became largely filled with sediment (Ingersoll, 1976). Subduction continued, however, until the early to

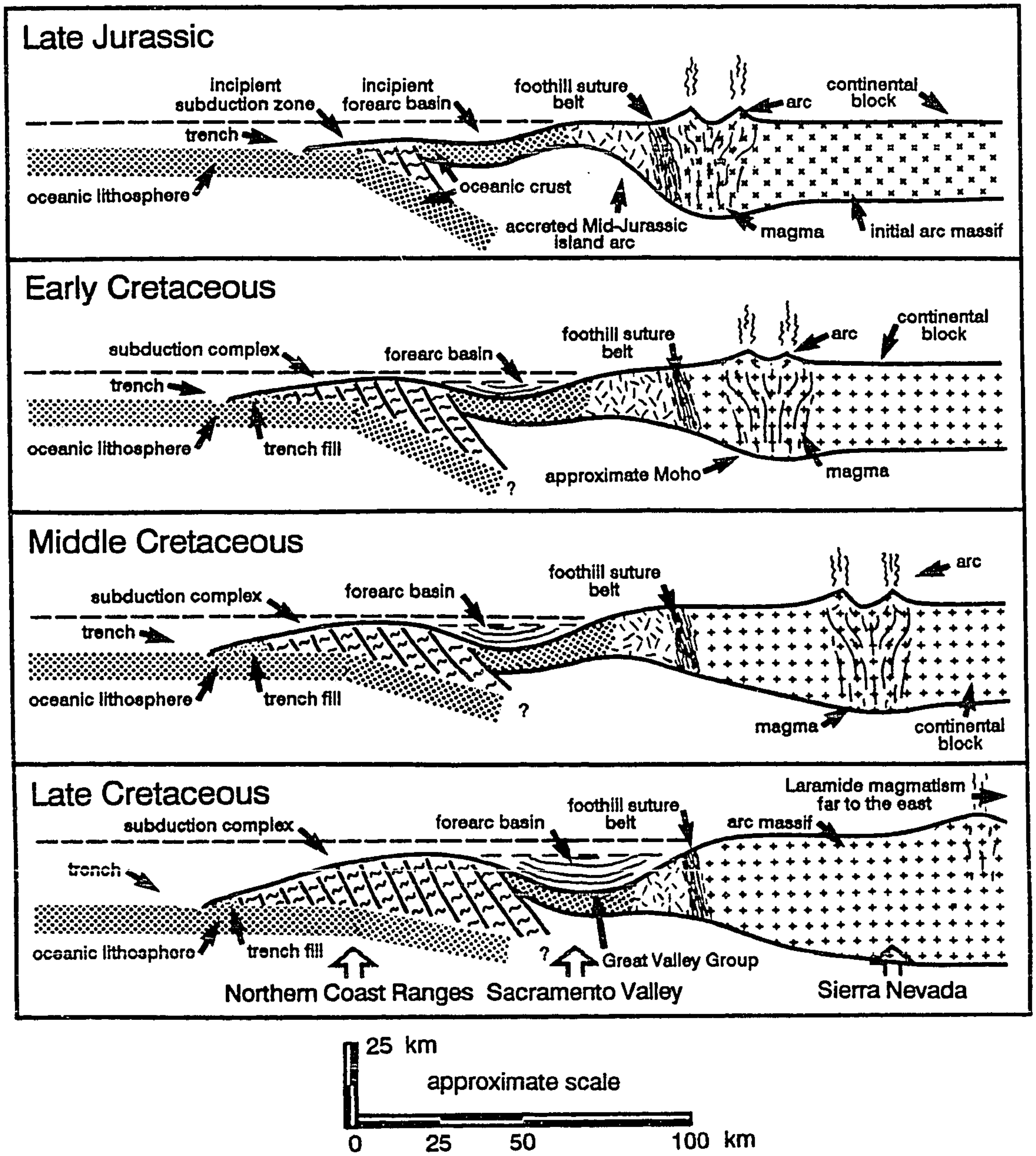


Figure 5. Inferred schematic plate tectonic setting and evolution of the Great Valley forearc basin from the Late Jurassic to the Late Cretaceous (modified from Dickinson and Seely, 1979).

middle Miocene, when the Farallon spreading center reached the trench (Atwater, 1970).

Great Valley Group

The sediment that filled the Great Valley forearc basin presently consists almost exclusively of a succession of fine- to coarse-grained siliciclastic sedimentary rocks. These rocks were deposited in deep marine, shallow marine, and fluvial environments (e.g., Dickinson, 1971; Russell, 1988; Johnson, 1990; Moore, 1990). Collectively, those units that filled the Great Valley forearc basin compose the Great Valley Group (also known as the "Great Valley Sequence"). The stratigraphic succession of these rocks shows both local and regional progradational and retrogradational trends related to the interplay among basin subsidence, sediment influx, and eustatic sea-level oscillations.

The aggregate thickness of the Great Valley Group has been variably placed between 7500 m (25,000 ft) by Moxon and Graham (1987) and over 21,000 m (69,000 ft) by Anderson (1943). Kirby (1943c), Chuber (1962), Durham (1962), Hawley (1962), Lachenbruch (1962), Bailey et al. (1964), Ojakangas (1968), Bailey and Blake (1969), Morrison et al. (1972), Chapman et al. (1975), Suchecki (1984), Chapman and Bishop (1988), and Nilsen (1991) have placed the total thickness in the 9000- to 15,000-m (30,000- to 50,000-ft) range. These thicknesses were derived from composite stratigraphic sections, which some believe gives an exaggeration of the thickness (Suppe, 1979; Ramirez, 1990).

Short and Ingersoll (1990a, 1990b) have concluded that during the Early Cretaceous sediment in the northern Sacramento basin was primarily derived from the Klamath Mountains. This conclusion is supported by the presence of a thick wedge of clastic material that onlaps the basement rock of the Klamath Mountains in the northern Sacramento basin (Short and Ingersoll, 1990a, 1990b). They believed that over time the Klamath Mountains were lowered by erosion and contributed less sediment to the basin.

As the Klamath Mountains waned as a primary sediment source for the Great Valley forearc basin, the Sierra Nevada was beginning to contribute vast amounts of detritus into the basin as it became tectonically active during the early Late Cretaceous. Numerous petrographic studies (e.g., Swe, 1968; Dickinson and Rich, 1972; Ingersoll, 1976, 1983) support this idea. In the north-central Sierra Nevada, the Cathedral Range intrusive epoch began in the Cenomanian and lasted well into the Campanian (Evernden and Kistler, 1970). Ingersoll (1976) suggested that erosion of volcanic rocks related to the Cathedral Range intrusive epoch may have been responsible for the large amounts of volcanic-derived sediment contributed to the forearc basin during this time.

Sierra Nevada

The granitic plutons of the Sierra Nevada batholith represent the eroded roots of a volcanic chain that stood parallel to the Franciscan trench (Ingersoll and Dickinson, 1981). These plutons represent intrusive events that were associated with the Nevadan and later orogenies (e.g., Bateman and Clark, 1974; Schweickert, 1981; Bateman, 1981, 1983).

The igneous rocks of the western Sierra Nevada are characterized by felsic plutonic rocks consisting essentially of tonalite. Quartz monzonite and granodiorite are more typical of the eastern Sierra Nevada. Sediment derived from these rocks includes about equal amounts of alkali feldspar and plagioclase, and a smaller percentage of quartz (Bateman and Wahrhaftig, 1966). Augite typically is the principal mafic mineral in these rocks.

Franciscan Assemblage

The oldest strata of the Great Valley Group in the northern Coast Ranges were deposited on a disrupted Upper Jurassic ophiolite (Bailey et al., 1970; Lanphere, 1971). Structurally below these rocks is an assemblage of marine sedimentary and volcanic rocks known as the Franciscan assemblage (e.g., Suppe and Armstrong, 1972; Blake and Jones, 1981; Aalto, 1982; Blake et al., 1985). Generally, the Franciscan assemblage is inferred to be a wedge of mélange and structurally imbricated rocks that were formed by incremental accretion and subduction of oceanic material at a convergent continent-ocean margin beginning in the latest Jurassic (Ernst, 1970; Maxwell, 1973). Recent studies suggest that the tectonic history of the Franciscan assemblage was considerably more complex than originally believed, and may involve lateral translation of rock assemblages and extension, as well as subduction-related accretion (Blake et al., 1985).

Rocks of the Franciscan assemblage are distinctive because of their mineralogy, which is important in provenance studies. Typical rocks of the Franciscan assemblage include quartz-rich mica schist, metamorphosed graywacke, argillite, and radiolarian chert. Also present are serpentinite and blueschist (Aalto, 1982).

Klamath Mountains

The Klamath Mountains of northwestern California and southwestern Oregon consist largely of igneous and metamorphic rocks (Irwin, 1981). The dominant structural features of the Klamath Mountains, as in the Coast Ranges, are related to subduction and accretion of exotic terranes, primarily during the Mesozoic. The eastern Klamath Mountains are believed to be part of a long-lasting volcanic arc built on oceanic crust and upper mantle rock that are today represented by the Trinity ophiolite (Irwin, 1985). Intermittent volcanism occurred from the early Paleozoic through the Jurassic (Irwin, 1981).

Rocks of the western Klamath Mountains include metamorphosed felsic, intermediate, and mafic volcanic and plutonic rocks, dismembered ophiolitic mélange, abundant chert, and high- and low-grade mica schist and metasedimentary rocks (Irwin, 1981; Short and Ingersoll, 1990a, 1990b). Because many of the rock types in the Klamath Mountains are compositionally similar to rocks in the Sierra Nevada, distinction of source terranes from the petrographic study of sandstones in the Great Valley Group has required a large amount of study (e.g., Chuber, 1961; Swe, 1968; Dickinson and Rich, 19872; Ingersoll, 1976).

METHODS AND PROCEDURES

Field Work and Outcrop Descriptions

Stratigraphic sections selected for detailed analysis were measured using a 1.5-m (approximately 5-ft) Jacob's staff and Brunton compass. All beds exceeding 6 cm (2.5 in) in thickness were described and the following information recorded: rock type, bed thickness, grain size (Udden-Wentworth scale), overall grain-size trend, sedimentary and biogenic structures, parts of the Bouma sequence present, and the nature of the bed's contact with the underlying unit. This information helped in establishing the inferred depositional environment (facies association) and the Mutti and Ricci Lucchi facies. A computerized graphics program transcribed this information into annotated stratigraphic columns at a scale of 5 m (16.5 ft) per page.

Paleocurrent data were collected by measuring lineations formed by flute casts and other indicators where the downcurrent flow direction can be deduced. Paleocurrent measurements were corrected for tectonic tilting and statistically analyzed using a series of templates developed by Mustard (1989). The computerized procedure involved correction of linear orientation data for regional dip and plunge. Statistical analyses evaluated vector mean and magnitude (method of Potter and Pettijohn, 1977), the Rayleigh significance value (from Curray, 1956), and circular standard deviation and variance (method of Krause and Geijer, 1987). Circular histogram (rose diagram) data were computed using the methods of Nemec (1988) and Andreassen (1990).

Petrography

Sandstone samples used for petrographic analysis were collected from outcrop exposures of minimally weathered beds. For comparative reasons, modal analyses were performed using the techniques developed Dickinson (1970), Dickinson and Rich (1972), Ingersoll (1976, 1978a), and Dickinson and Suczek (1979).

To avoid bias introduced by variability in grain size, most samples were collected from massive, medium-grained sandstones. All samples were cut perpendicular to bedding, and all were impregnated with blue epoxy. Half of each section was stained for plagioclase using barium chloride and rhodizonate, and for potassium feldspar using sodium cobaltinitrite as suggested by Graham et al. (1976).

Point counts were performed using a mechanical point-counting stage mounted on a Leitz monocular petrographic microscope. Three hundred points were counted on each slide with a grid spacing slightly exceeding the maximum grain size (normally spaced at 1.0 mm (0.04 in)).

Generally, only high power (400X) was used during the point-counting process, although lower powers (80X and 20X) often were utilized to obtain a larger field of view. No grain was counted more than once, and all mineral constituents greater than 0.0625 mm (0.00245 in) were counted as framework minerals even if they were part of a larger rock fragment.

Sample localities and the relative stratigraphic positions of samples were masked during the counting process in order to minimize any influence that such information might have on the point counts. During the early phase of point counting, both the stained and unstained sides of the thin section were counted to ascertain the usefulness of the staining process. It was quickly realized that the feldspar staining greatly helped in identification, and so all later counts were restricted to the stained part of the thin section.

Point counts were performed using the Gazzi-Dickinson point-counting method (Dickinson, 1970; Ingersoll et al., 1984). Lithic parameters and definitions follow those outlined by Dickinson (1970), Dickinson and Rich (1972), and Ingersoll (1983). Provenance interpretations were made by comparing the results with those of Dickinson and Rich (1972), Dickinson and Suczek (1979), Ingersoll (1976, 1979, 1983), and Bertucci and Ingersoll (1983). All slides have been filed at the Department of Geology at San Jose

State University.

In addition to the petrographic work, a pebble count was performed on a conglomerate within the Guinda Formation at Putah Creek. Fifty clasts were counted at each of 10 different exposures, for a total count of 500 individual pebbles. The count was conducted by visually delimiting an area of the outcrop and identifying all the pebbles and cobbles within its perimeter. These data, as well as all other relevant information, were useful in developing ideas concerning provenance and sediment dispersal patterns.

Biostratigraphy

Shale and claystone were collected for the extraction of microfossils from outcrops that exhibited minimal weathering. The original sample size was about 500 ml in volume.

Separation of microfossils from the shale and claystone was performed using kerosene and water. This procedure involves initial crushing of the rock into pea-sized or smaller fragments, placing the fragments into a Pyrex beaker, and heating the sample in an oven at about 70°C (160°F) until thoroughly dry. The dried sample is then placed in kerosene and left to soak until the kerosene has completely permeated the rock. The excess kerosene is then decanted from the beaker and a mixture of hot water and a small amount of dispersant (tri-sodium phosphate) is added to the sample. The liquid is decanted, and more hot water and dispersant are added to break down any remaining aggregate. All samples were then rewashed using Quaternary "O" (a compound used to expand clays). The sample was then sieved using three Tyler mesh screens numbered 30, 120, and 200 (0.59 mm (0.023 in), 0.125 mm (0.0049 in), and 0.074 mm (0.0029 in) mesh-openings, respectively). The final residue was then picked for microfossils under a low-power microscope. All recognizable adult foraminifera recovered are on deposit in the micropaleontological laboratory of UNOCAL, located in Ventura, California.

Core Study

A core that penetrated the Guinda Formation was examined and described at the California Well Sample Repository located at California State University, Bakersfield. The core was described using the same general methods used for describing measured outcrop sections, with some modification due of the nature of the core. The core examined for this study is available for examination at the Repository.

Well-log Interpretation

Electric logs were used primarily for the interpretation and correlation of wells drilled in the Sacramento Valley, as this log type is most useful for showing lithology, grain-size trends, and bed boundaries. Spontaneous potential (SP) and induction resistivity logs, at a scale of 1 inch equal to 100 ft (approximately 1 cm equal to 12 m), were obtained from Petroleum Information in Bakersfield. Normally, full log suites were studied and all relevant formational contacts were established prior to delineating internal packages within the Guinda Formation. All logs used in this study are in the public domain and available for inspection.

LITHOSTRATIGRAPHY

The Guinda Formation was named for the town of Guinda, California, located in the Capay Valley on the western side of Cache Creek (fig. 3). This formation was first described by Kirby (1941, 1942) and formally named in 1943 (Kirby, 1943c). Kirby's type locality of the Guinda Formation is located along the headwaters of Salt Creek and Petroleum Creek on the northeastern flank of the Capay Hills (Kirby, 1943c).

The Guinda Formation is a unit of thick- to very thick-bedded sandstone and minor interbedded shale that crops out along the eastern margin of the northern and central Coast Ranges from near Vacaville in the south to the shores of Black Butte Reservoir in the north, a distance of approximately 165 km (100 mi). In the subsurface, it underlies the western portion of the northern and central Sacramento Valley, where it can be seen on geophysical well logs from the outcrop belt to approximately 50 km (30 mi) to the east.

The contact between the Guinda Formation and the Funks Formation is conformable. Kirby (1943c, p. 284) placed the Funks-Guinda formational contact "below sandstones of the Guinda Formation." The author places the contact at the base of the lowermost sandstone bed in the Guinda Formation thicker than approximately 15 cm (6 in) below which is the

the thick, predominantly shale sequence of the Funks Formation. Sandstone beds within the Funks Formation are thin (less than 15 cm (6 in)) and poorly exposed. Whereas the formational contact is generally poor, good exposures are located along the stream banks of Alamo Creek in Gates Canyon and along the shores of Black Butte Reservoir when the water is low. Court (1966) also reported an excellent exposure of this contact just east of Arbuckle Road in the northwestern Capay Hills (fig. 3), where about 30 m (100 ft) of section is exposed in a small creek bed.

The contact between the Guinda Formation and the overlying Dobbins Shale Member of the Forbes Formation is conformable and generally sharp. Kirby (1943c, p. 283) placed the Guinda-Forbes formational contact "below the basal foraminiferal shale member of the Forbes Formation." The author places the contact at the top of the uppermost sandstone bed thicker than approximately 15 cm (6 in) in the Guinda Formation above which is the thick shale sequence of the Dobbins Shale Member of the Forbes Formation. Generally only thin-bedded stringers of sandstone, less than 2.5 cm (1 in) in thickness, are present in the Dobbins Shale Member of the Forbes Formation. The shales of the Guinda Formation can be distinguished from those of the Dobbins Shale Member of the Forbes Formation by the lack of calcareous concretions that are prevalent throughout the Dobbins Shale Member of the

Forbes Formation. Excellent exposures of the upper contact of the Guinda Formation occur along the shores of Black Butte Reservoir, along Salt Creek in the Capay Hills, and along Alamo Creek in Gates Canyon. In the southern part of the Capay Hills, the Pliocene and Pleistocene Tehama Formation lies unconformably above the poorly exposed Guinda Formation.

The color and weathering characteristics of the Guinda Formation vary widely, but compositionally and texturally this unit is remarkably uniform throughout its extent. Typically, the sandstone of the Guinda Formation consists of medium- to coarse-grained, subangular to subrounded sand; beds have a yellowish to brownish-gray (5Y 8/1 to 5Y 6/1) color in weathered samples. Darker, iron-stained sandstone is typical of deeply weathered surfaces. Fresh, unweathered sandstones of the Guinda Formation generally are light gray to light olive gray (N7 to 5Y 6/1) in color. Thin and wispy shaly layers are common in unweathered sandstone samples. Most of the sandstone consists of approximately equal amounts of quartz and feldspar, with a lesser percentage of lithic fragments. Some beds contain layers of large biotite and muscovite flakes.

Individual sandstone beds can exceed 3 m (10 ft) or more in thickness, but they generally are much thinner. Many of the sandstone beds are massive at the base (Bouma T_a), with planar bedding (Bouma T_b) and convolute bedding with ripple laminations (Bouma T_c) near the tops of some the beds. Amalgamated sandstone beds also are common. Shale rip-up clasts are locally abundant within the sandstone beds, with some shale clasts exceeding 50 cm (20 in) in length. Interbedded with the sandstone are minor siltstone and shale beds (Bouma T_e) that generally are less than 20 cm (8 in) in thickness and only rarely exceed 1 m (3 ft) in thickness. These fine-grained rocks commonly exhibit abundant horizontal laminations, rare ripple marks, local concretions, and abundant plant debris.

One of the most characteristic features of the Guinda Formation is the abundance of calcareous, nearly spherical "cannonball" concretions, which range in diameter from 3 to 300 cm (0.1 to 10 ft). These concretions, typically exposed along Salt Creek in the Capay Hills, appear to be lithologically identical to the surrounding rock except that they have been rendered harder, less permeable, and thus more resistant to weathering, by cementation with calcium carbonate. Generally, the concretions are darker in color than the surrounding sandstone. "Cannonball" concretions occur throughout the Upper Cretaceous rocks of the Great Valley Group, particularly the Sites Formation, but those in the Guinda Formation are more abundant and are much larger than those from any other unit of the Great Valley Group.

Another lithologic characteristic of the Guinda

Formation is the presence of small ferruginous concretions. These concretions range in size from 1 to 6 cm (0.5 to 2.5 in) in diameter. These orange-colored concretions are locally abundant, especially in the upper portions of the Guinda Formation, as along the South Fork of Willow Creek. Elsewhere in the Great Valley, this type of concretion has been observed only in the Ione Formation (R.S. Creely, written comm., 1991), the Capay Formation, and the unnamed middle and upper members of the Forbes Formation.

Kirby (1943c) recognized that the basal portion of the Guinda Formation at the type locality is truncated by the Sweitzer fault. Kirby (1943c) calculated that the Guinda Formation is 425 m (1400 ft) thick in this area by combining measurements taken from outcrop and from two nearby wells where the lower contact of the Guinda Formation is present. Unfortunately, his choice of wells proved to be ill-suited for establishing the true formational thickness because they both were drilled through steeply dipping and structurally complex strata, problems which apparently never were accounted for by Kirby. Additionally, based on his lithologic descriptions, it also appears that Kirby (1943c) incorporated rocks that now are considered to be parts of the overlying Dobbins Shale Member of the Forbes Formation and a portion of the unnamed middle member of the Forbes Formation into the Guinda Formation (called unit "KC2" in his illustrations).

Research by the author indicates that the thickness of the Guinda Formation averages several hundred feet less than was quoted by Kirby (1943c), averaging instead about 200 m (700 ft) in thickness and only rarely exceeding 300 m (1000 ft).

Kirby (1943c, p. 283) also designated the area "along the faulted western slope of the Rumsey Hills, between the latitudes of the town of Rumsey on the north and Tancred on the south," as exhibiting typical exposures of the Guinda Formation. However, detailed mapping by this author indicates that the Guinda Formation does not crop out in the Capay Hills south of an east-west line located approximately 3 km (2 mi) north of Tancred.

Foraminiferal research by Goudkoff (1945) and Douglas (1962), as well as detailed stratigraphic work by Emerson and Roberts (1962) and by this author, shows that Kirby also miscorrelated the section of the Guinda Formation that he measured along Putah Creek (fig. 3). At this locality, Kirby (1943c) interpreted portions of the underlying Funks Formation and the overlying Forbes Formation as part of the Guinda Formation.

Despite the wealth of paleontologic data gathered in the Putah Creek area, the stratigraphy of this area has continued to be miscorrelated. Switzer (1962) showed the Guinda Formation as pinching out just north of the Putah Creek area, whereas in the same area Ingersoll (1976, 1981) measured more than 1250 m (4100 ft) of the Guinda Formation; apparently, like Kirby (1943c), Ingersoll included a large portion of the overlying Forbes Formation as part of the Guinda Formation. In contrast to this previous work, detailed stratigraphic work by the author in this area indicates that the Guinda Formation is slightly less than 300 m (1000 ft) thick.

The stratigraphic complexities of the Putah Creek area have traditionally proved troublesome, prompting Shell Oil Company in 1951 to conduct a detailed coring and sampling program to try to resolve some of the conflicting data gathered along Putah Creek. Some of the results of Shell's program were published by Stinemeyer (1979); surprisingly, some of the formational boundaries of the Great Valley Group shown on the map presented in his report are inconsistent with the data obtained from the cores.

Additional mapping by the author indicates that the Guinda Formation south of Putah Creek also has been miscorrelated and incorrectly mapped. Whereas Sims et al. (1973) correctly extended the Guinda Formation south of Putah Creek into the Vaca Mountains, they incorrectly correlated part of the lower Forbes Formation with the Guinda Formation and the Guinda Formation with part of the upper Sites Formation. Emerson and Roberts (1962) correctly mapped the formational boundary of the Guinda Formation in this area, although they and Nilsen (1990) showed the Guinda Formation pinching out just south of Ulatis Creek in the Mix Canyon area (fig. 3). Field work for this report indicates that approximately 2.5 km (1.5 mi) south of Mix Canyon in the Gates Canyon area, a thick section of the Guinda Formation is present.

Even recent geologic maps in the Vaca Mountains area (Wagner and Bortugno, 1982; Chapman and Bishop, 1988), have incorrectly shown the formational boundaries and location of the Guinda Formation and parts of adjacent units. Because accurate mapping and correlation within the Great Valley Group have been difficult, several workers have lumped stratigraphic units together, or they have referred to them by names other than those proposed by Kirby. Various units that include rocks of the Guinda Formation include "unit 9" (Brown and Rich, 1961), "Kcgg" (Rich, 1968), "unit VI" (Ojakangas, 1968), "unit IVc" (Swe and Dickinson, 1970), "unit 3" (Rich, 1971), or the Guinda Sandstone Member of the Rumsey Formation (Ingersoll, 1976).

Description and Interpretation of Outcrop Sections

Introduction

In order to better understand the stratigraphic nature of the Guinda Formation, six outcrop sections located along the eastern foothills of the Coast Ranges were measured, described, and interpreted. The information collected at each section includes detailed bed-by-bed descriptions, interpreted Mutti-Ricci Lucchi facies associations, and Bouma turbidite divisions. From north to south, the six localities studied are located at: (1) Black Butte Reservoir, (2) South Fork of Willow Creek, (3) Salt Creek in the Capay Hills, (4) Bray Canyon on the north side of Putah Creek, (5) Ulatis Creek in Mix Canyon, and (6), Alamo Creek in Gates Canyon (fig. 6). See Appendix 1 for the detailed outcrop descriptions.

Black Butte Reservoir Section

<u>Description</u>. A very good and complete exposure of the Guinda Formation lies along the shores of Black Butte Reservoir (SE sec. 31, T.21N., R.4W.), located near the Tehama-Glenn County border. Figure 7 is a geologic map of this area. This locality represents the most northerly exposure of the Guinda Formation along the western margin of the Sacramento Valley.

During high water, the rocks exposed along the shores of the lake are cleaned and cleared of most vegetation and debris, making for spectacular exposures when the water level is low. The best time to observe these rocks is during the late fall and early winter.

Nearly 120 m (400 ft) of the Guinda Formation is exposed at Black Butte Reservoir. This measured section is shown at a reduced scale in Figure 8. These rocks are

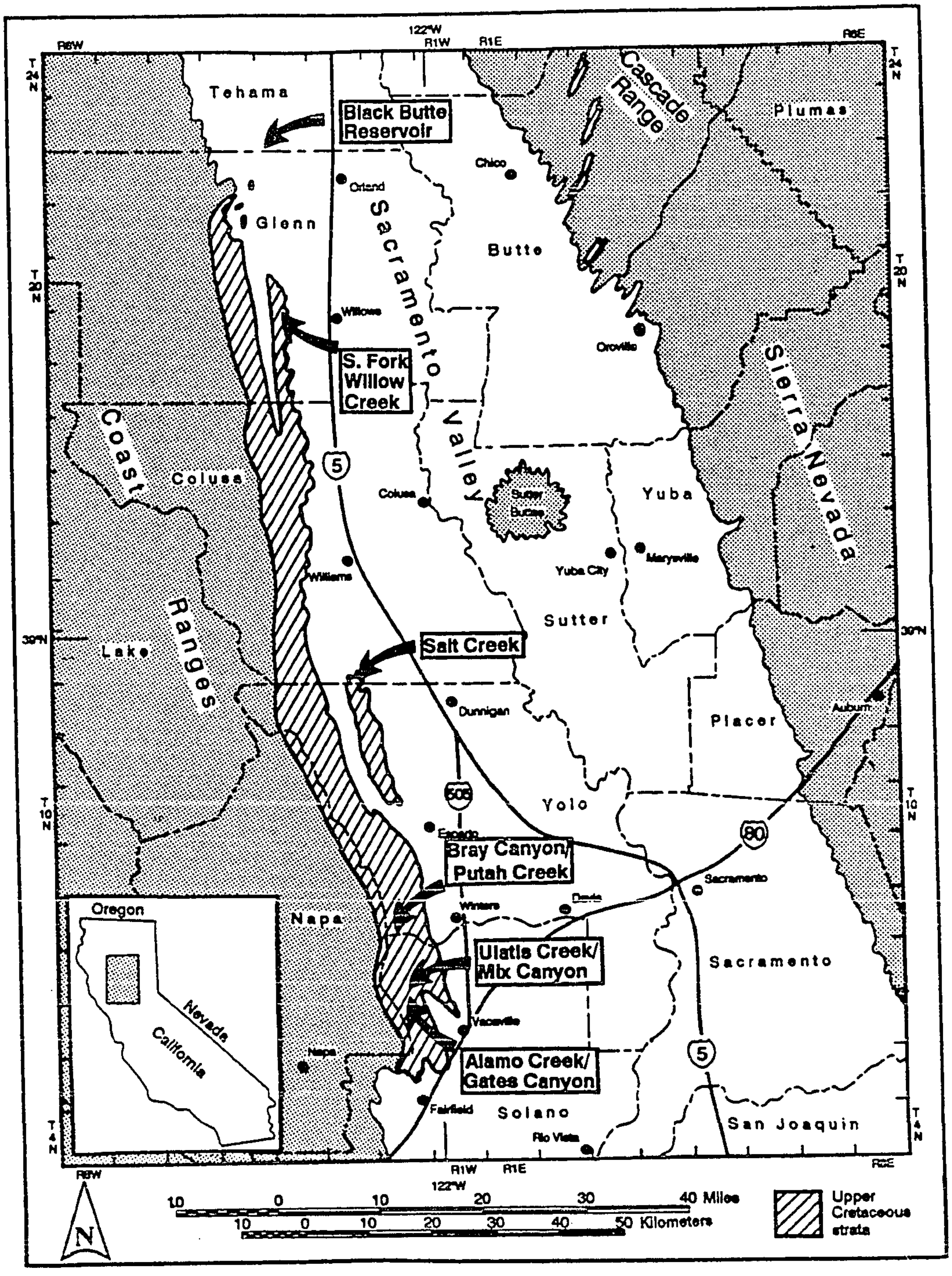


Figure 6. Location of measured sections.

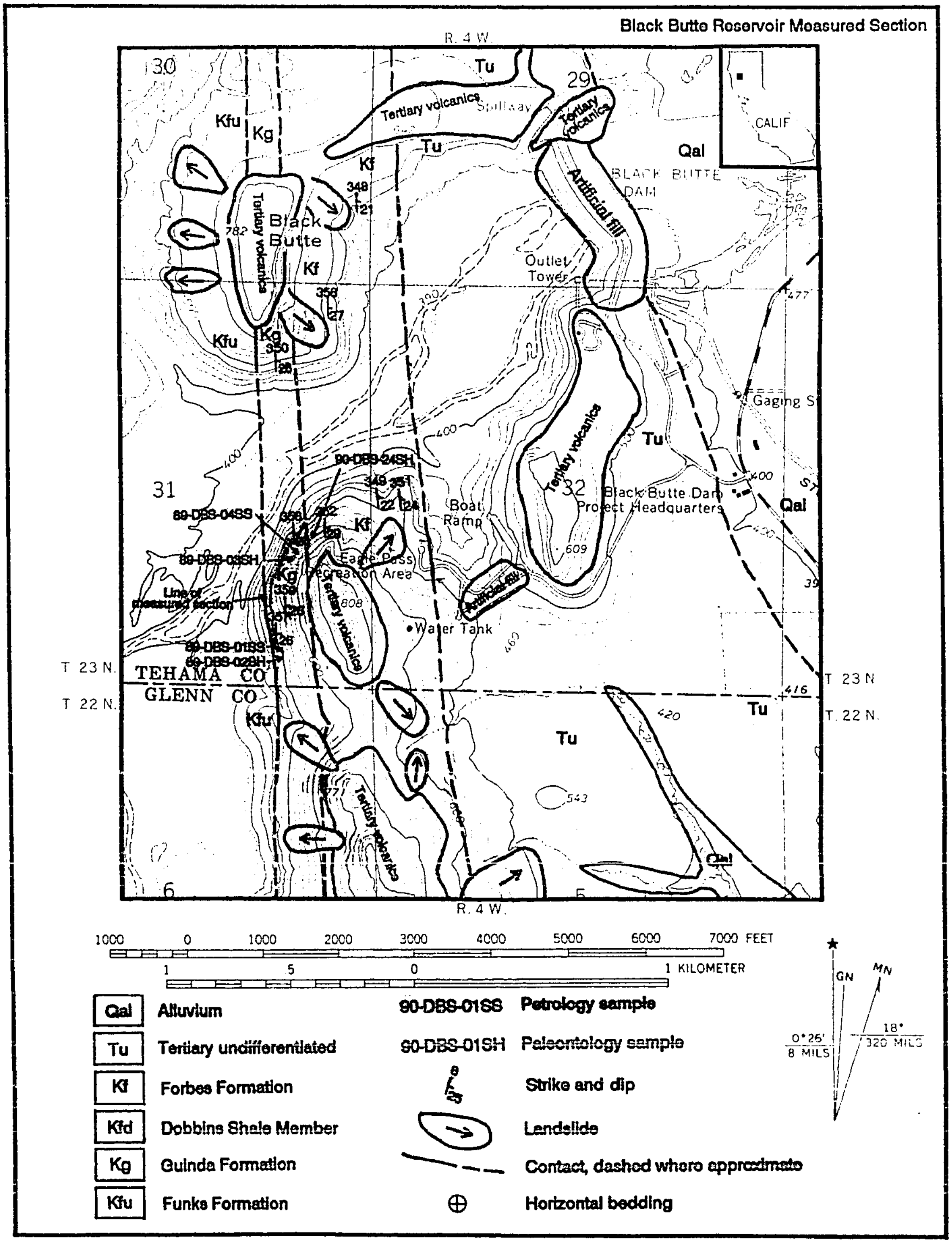


Figure 7. Geologic map of the Black Butte Reservoir area (Black Butte Dam 7.5-minute quadrangle).

dominated by thick-bedded, generally fine- to medium-grained sandstone, interbedded with thin-bedded siltstone and shale. Bedding dips eastward at about 26°. The north-trending Willows fault was mapped by Chapman et al. (1975) along the western edge of the outcrop belt, but there is no evidence for its presence in the rocks of the Guinda Formation at Black Butte Reservoir. The uppermost Funks Formation and the lower and middle Forbes Formation also crop out along the shores of the lake so that the entire Guinda Formation is exposed.

The basal 52 m (170 ft) of the Guinda Formation consist of several nonchannelized thickening- and coarsening-upward sandstone bodies. Each body averages 3 to 5 m (10 to 15 ft) in thickness (fig. 9). The thickest sandstone body is just under 8 m (25 ft) in thickness, and the thinnest is about 2 m (6 ft) thick. Many of the sandstone beds that make up each sandstone body are amalgamated, although thin shale partings locally occur between them. Sandstone beds can be traced laterally for several hundred meters. Dominating each sequence are Facies B beds, which consist of coarse- to medium-grained massive sandstone with local, thin interbeds of siltstone and shale; Facies C beds, consisting of interbedded coarse- to fine-grained sandstone with siltstone and shale that are organized into Bouma sequences that contain the lowermost

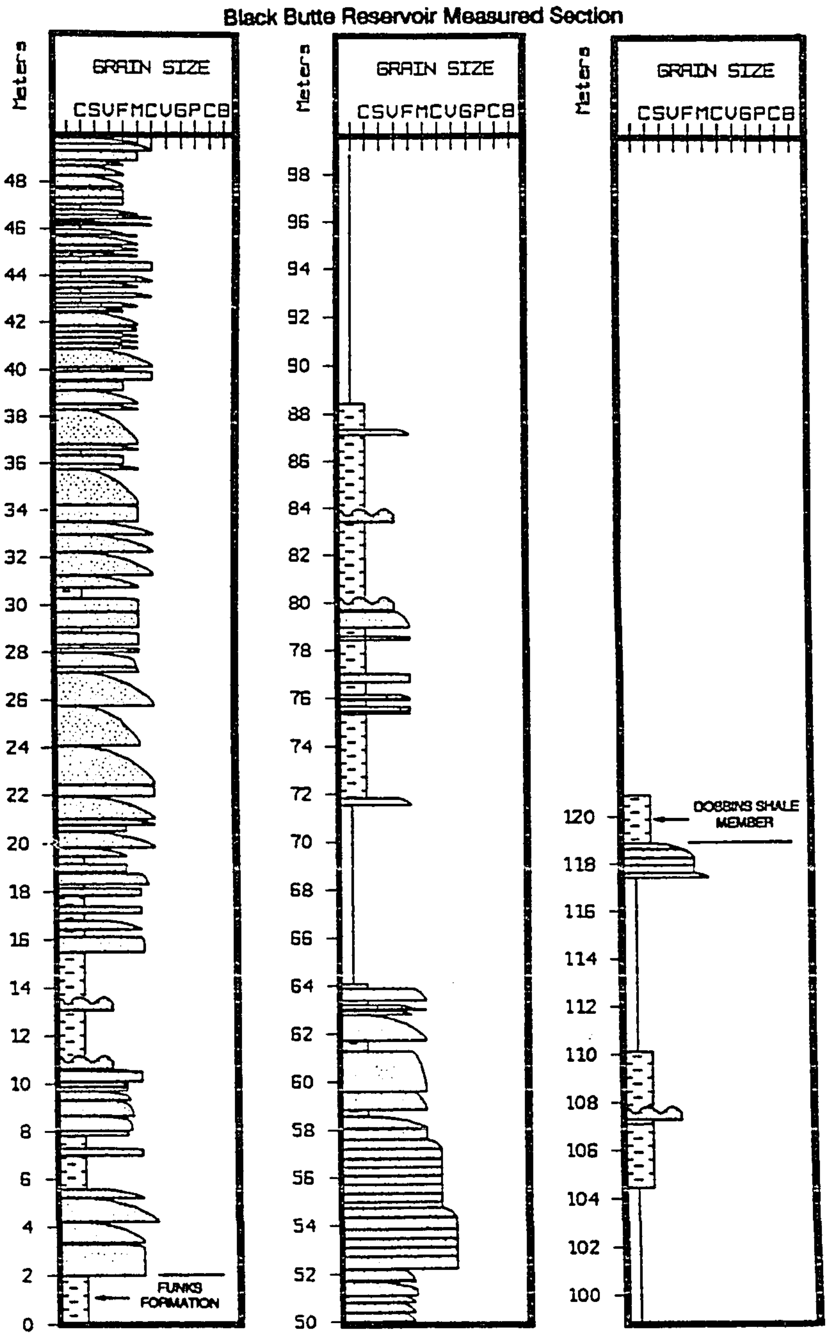


Figure 8. Generalized measured section of the Guinda Formation at Black Butte Reservoir. See Appendix 1 for the explanation and a detailed outcrop description.

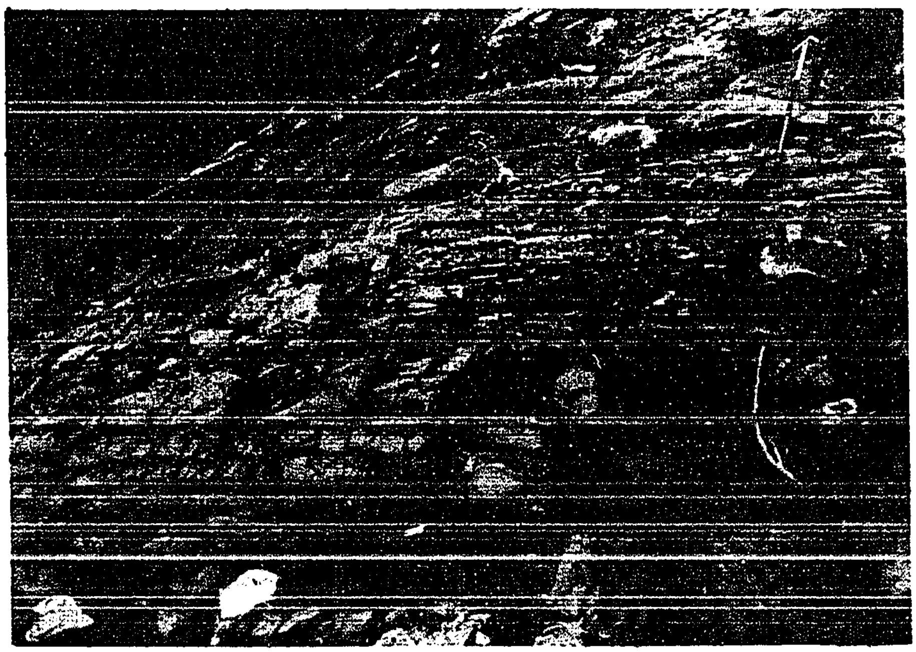


Figure 9. A series of stacked, thickening- and coarsening-upward sandstone bodies in the lower portion of the Guinda Formation at Black Butte Reservoir. A 1.5-m (approximately 5-ft) Jacob's staff in upper right-hand corner for scale.

massive T_a division; Facies D beds, which are similar to Facies C beds, but lack the lowermost T_a division; and Facies G beds, which consist of pelagic and hemipelagic shale with local interbeds of siltstone and fine-grained sandstone.

Basal contacts of the sandstone beds typically are irregular. Shale rip-up clasts, 1 cm to 0.5 m (0.5 in to 3 ft) in length, commonly occur near the base of many of the sandstone beds (fig. 10), although some shale rip-up clasts occur near the tops of these beds. Some clasts are crudely imbricated, suggesting a southerly direction of flow. Soft-sediment deformational features in these beds include pinching and swelling of thin shale beds, flame structures, convolute bedding (fig. 11), slump-fold features (fig. 12), wispy clay and silt, and load structures. Spherical concretions, some reaching 3 m (10 ft) in diameter, occur in many of the beds. Flute casts and other sole markings on the bases of sandstone beds also are present in large numbers.

Minor thickening- and coarsening-upward sequences of sandstone beds, generally less than a meter in thickness, occur within some of the thicker coarsening- and thickening-upward units. These beds are most common in the lowermost part of this section.

Thick bodies of interbedded sandstone turbidites and shale occur between some of the large thickening- and

Figure 10. Shale rip-up clasts approximately 27 m (89 ft) above the base of the Guinda Formation at Black Butte Reservoir.

Figure 11. Flame structures and convolute bedding approximately 32 m (105 ft) above the base of the Guinda Formation at Black Butte Reservoir.

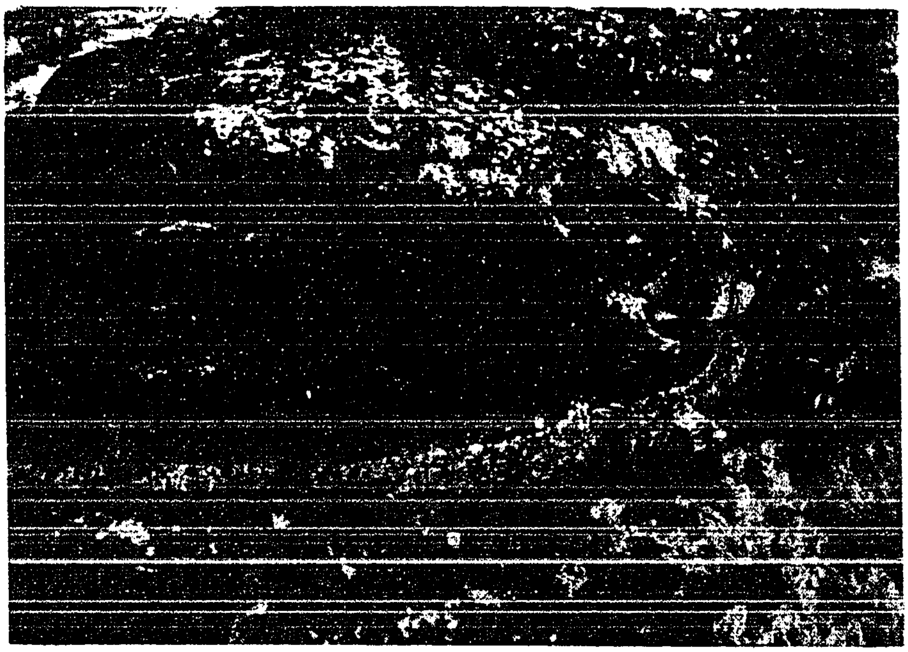


Figure 12. Recumbent isoclinal slump-fold approximately 38 m (125 ft) above the base of the Guinda Formation at Black Butte Reservoir.

coarsening-upward bodies. These turbidites range between 1.5 and 4 m (5 to 13 ft) in thickness, typically show low sandstone-to-shale ratios, and are dominated by abundant horizontal laminations, convolute bedding, and pinch-and-swell beds. These beds belong to Facies D and G.

From 52 to 64 m (171 to 210 ft) above the base of the section (fig. 8), approximately 12 m (40 ft) of fining- and thinning-upward sandstone units directly overlie the thick coarsening- and thickening-upward deposits. Five individual sandstone bodies, ranging in thickness from 0.7 to 4 m (2 to 13 ft) have been identified. Each sandstone body is dominated by Facies B beds that fine and thin upward. These beds generally are composed of coarse- to medium-grained, massive, planar-bedded sandstone. Amalgamated sandstone with low-angle climbing ripples near the tops of the beds are common in the lower two units. The upper sandstone beds, which commonly have shale breaks between the beds, generally are not as thick as the lower sandstone beds.

Thin-bedded turbidites having a fairly high sandstone-to-shale ratio compose the section from 64 m (210 ft) to the top of the measured section (fig. 8). These 55 m (180 ft) of thin-bedded turbidites are composed of shale and carbonaceous sandstone beds (fig. 13). The sandstone beds are primarily planar to ripple-cross-laminated, with many beds exhibiting lateral and vertical thickness variations.

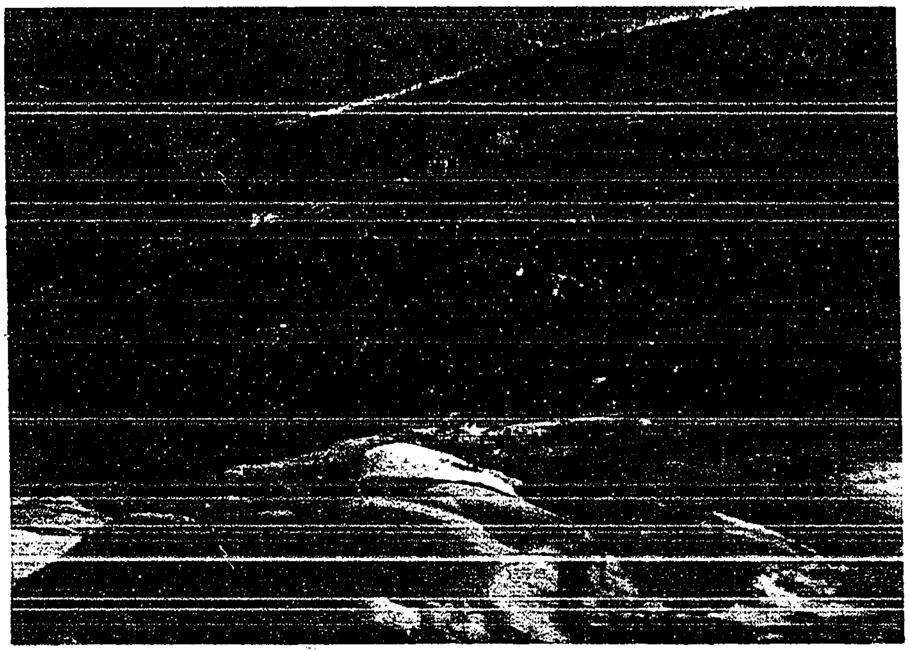


Figure 13. Abrupt change upward from thick, amalgamated, primarily massive and planar-laminated sandstone beds to thin sandstone with interbedded shale beds in the upper portion of the Guinda Formation at Black Butte Reservoir.

Facies D, E, and G beds dominate this section. Facies E beds consist of thinly interbedded sandstone and shale, and differ from the Facies D beds in that they have a higher sandstone-to-shale ratio, are thinner and have more numerous sandstone beds, and generally contain more discontinuous beds. The thin-bedded turbidites are not laterally continuous. Megafossils, principally Inoceramus fragments, locally are present. Situated within this turbidite sequence are two amalgamated Facies D sandstone beds, 0.7 and 1.5 m (2 and 5 ft) thick. These beds are dominantly planar bedded at the base and convoluted or ripple laminated at the top.

Interpretation. The basal portion of the Guinda Formation at Black Butte Reservoir is interpreted as consisting of 11 stacked outer-fan depositional lobes (as defined by Shanmugam and Moiola, 1991), shown at a reduced scale in Figure 14. Outer-fan depositional-lobe deposits are characterized by thickening- and coarsening-upward units which are laterally continuous and dominated by Facies B and C. These beds rest conformably above the Funks Formation and below the Dobbins Shale Member of the Forbes Formation, both of which have been interpreted as Facies G and representing basin-plain sedimentation.

The minor, repetitive, thickening- and coarsening-upward sequences of sandstone that occur within some of the lobe

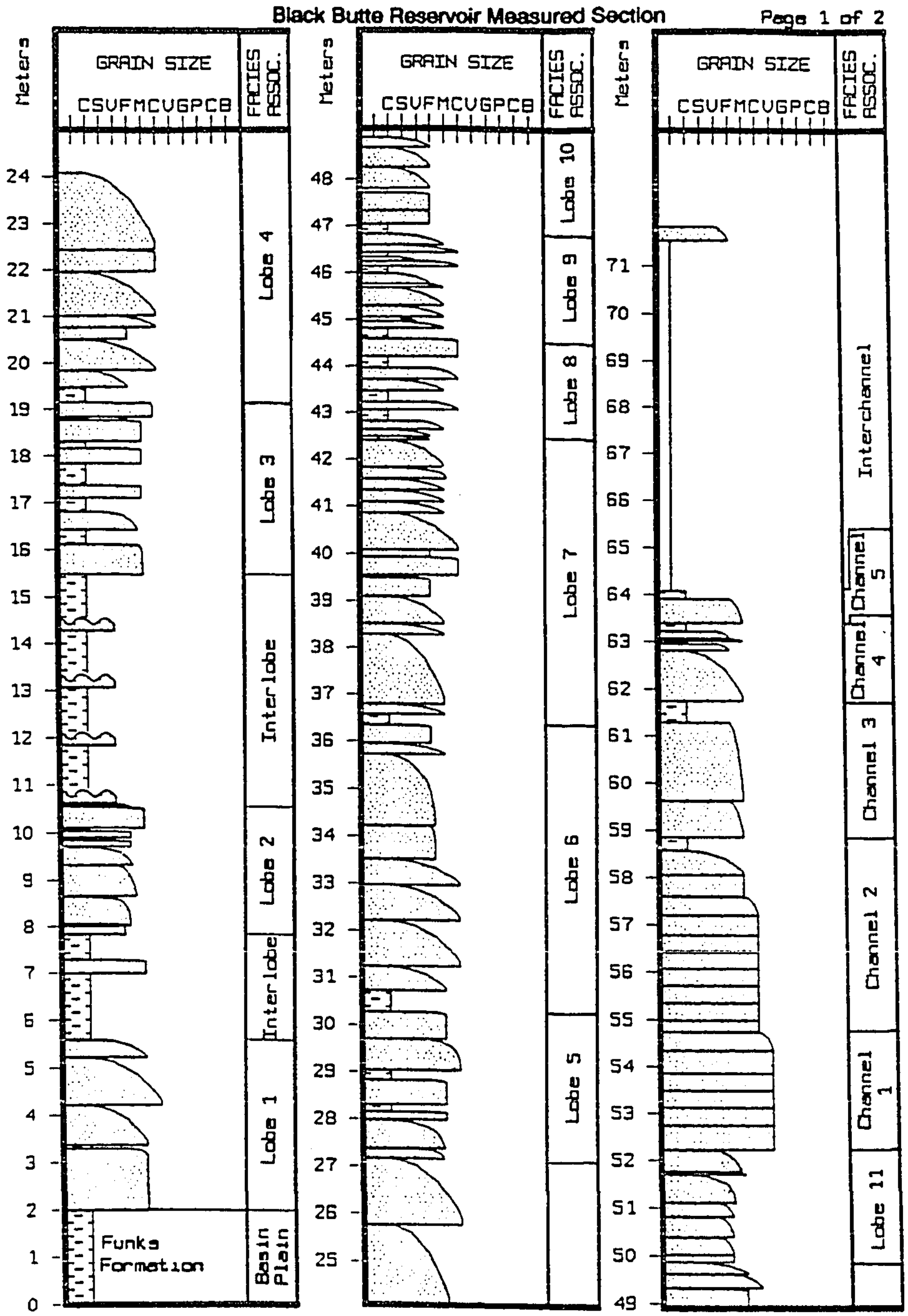


Figure 14. Measured section of the Guinda Formation at Black Butte Reservoir, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

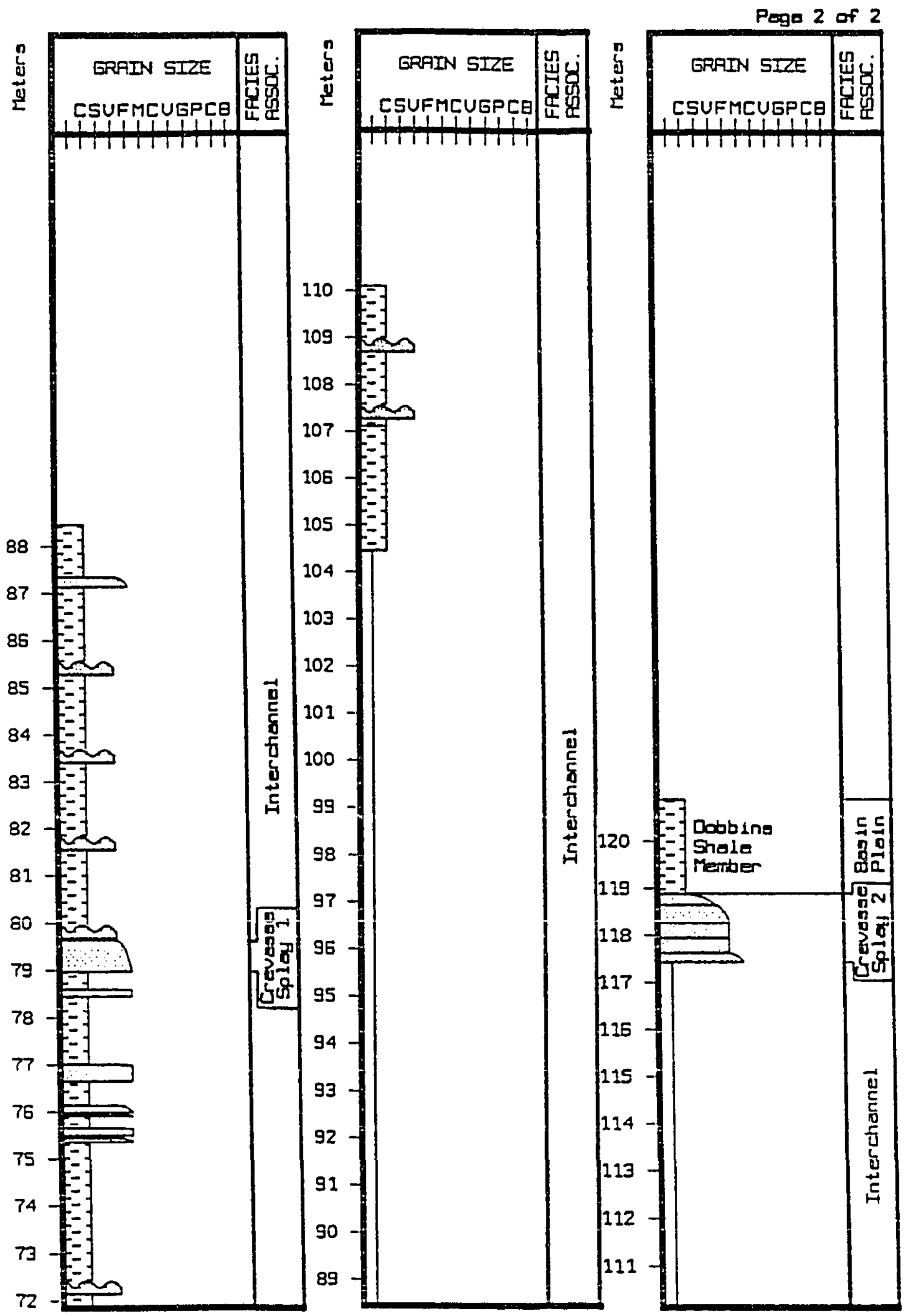


Figure 14 (cont'd).

deposits are believed to be compensation cycles (as defined by Mutti and Sonnino, 1981), because they show fewer well developed thickening- and coarsening-upward units than the depositional lobe deposits. These beds represent smoothing of topographic relief during progradation of individual sandstone lobes.

The presence of shale rip-up clasts in many of the sandstone bodies indicates that the turbidity flow was strong enough to cause detachment of mud fragments from the substratum and incorporation of these clasts into the turbidite flow. The presence of some of these clasts near the tops of beds, rather than the bottoms of beds, where they occur more frequently, suggests that the sand was quite fluid during deposition, allowing some of the clasts to "float" to the top of the flow.

Middle-fan channel deposits that directly overlie the depositional lobe deposits (fig. 14) represent progradation of the fan system basinward. These beds characteristically form Facies B fining- and thinning-upward sequences.

Approximately 64 m (210 ft) above the base of the section, directly overlying the channel deposits, is a thick sequence of thin-bedded turbidites that are dominated by Facies D, E, and G beds (fig. 14). These rocks are interpreted as representing interchannel, levee, and overbank deposits. This sequence displays a high sandstone-to-shale ratio, and individual beds are commonly rippled, convoluted, and laterally discontinuous. Two thick sandstone beds, situated 79 and 117 m (259 and 384 ft) above the base of the section (fig. 14), are interpreted as crevasse-splay deposits because they are thicker than the adjacent channel-levee deposits.

South Fork of Willow Creek Section

<u>Description</u>. Another complete section of the Guinda Formation is located along the South Fork of Willow Creek (NW SE sec. 9, T.19N., R.4W.). Figure 15 is a geologic map of this area. This section, near the southern terminus of the Hoodoo Hills in central Glenn County, can be best observed during times of low-water flow, because most of the rock exposures are along the bottom of the creek bed.

Approximately 214 m (700 ft) of section were measured at this locality. This measured section is shown at a reduced scale in Figure 16. These rocks are dominated by shale, medium- to coarse-grained sandstone, and conglomerate. The lower beds dip eastward at about 70°, with the dip shallowing to approximately 55° up section. The contacts with both the Funks Formation and the Dobbins Shale Member of the Forbes Formation are poorly exposed at this locality.

The basal 43 m (141 ft) of the Guinda Formation consists of several thick packages of generally coarse-grained sandstones that fine and thin to medium-grained

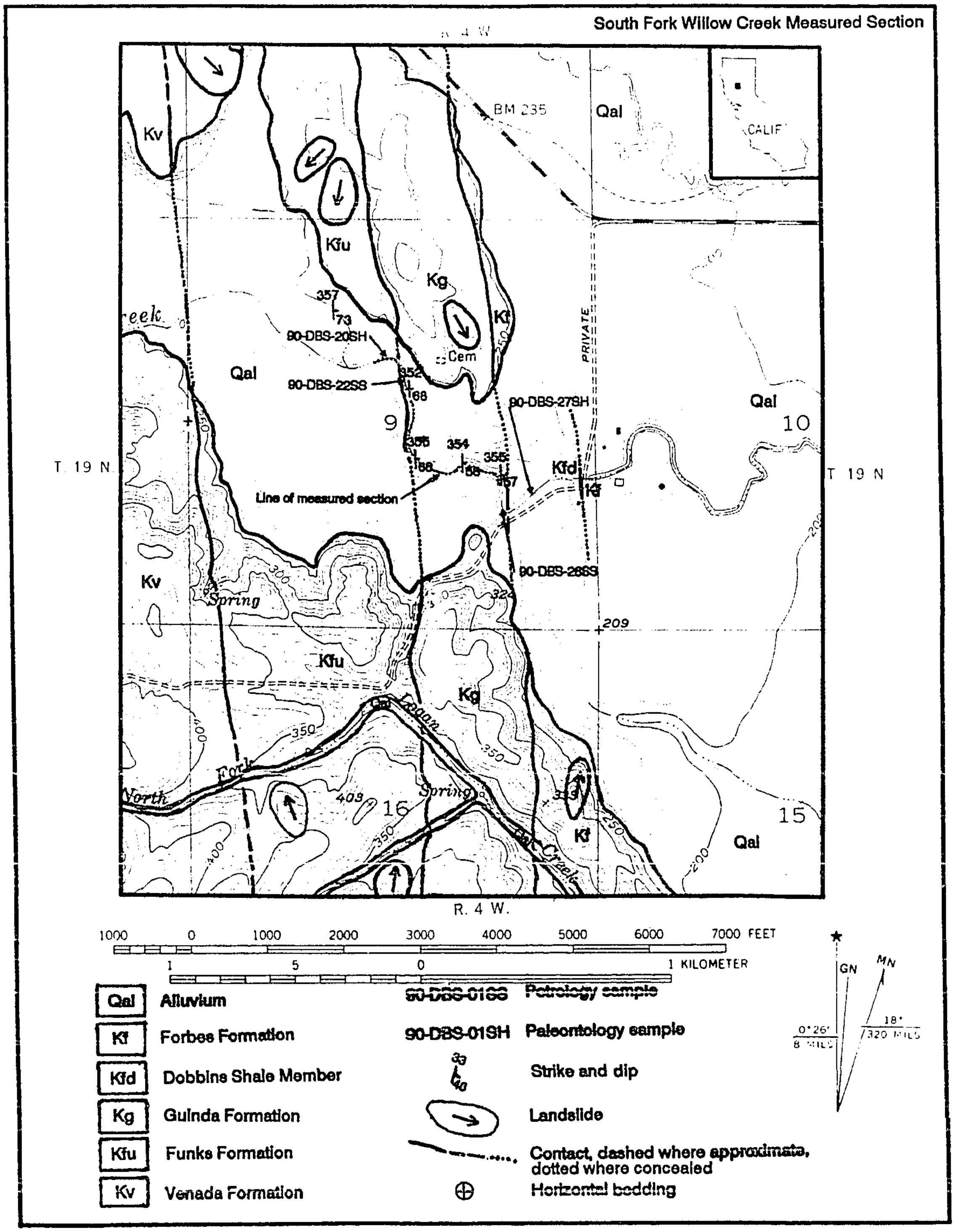


Figure 15. Geologic map of the South Fork of Willow Creek area (Stone Valley 7.5-minute quadrangle).

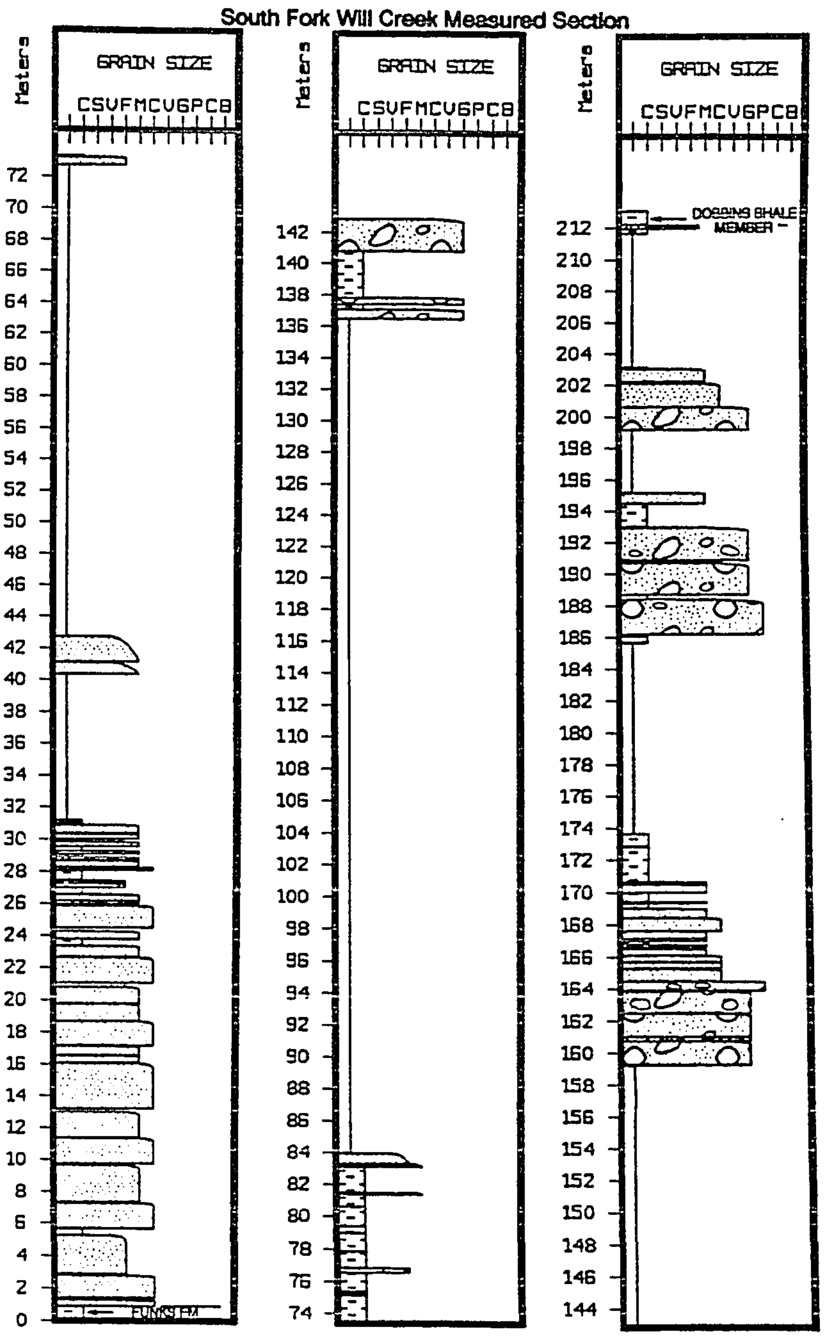


Figure 16. Generalized measured section of the Guinda Formation along the South Fork of Willow Creek. See Appendix 1 for the explanation and a detailed outcrop description.

sandstones upwards. These sandstone bodies are dominated by Facies B beds and average about 1 m (3 ft) in thickness. Typically, the basal part of each body is composed of massive sandstone and the upper part is overlain by thick-bedded, subparallel-laminated sandstone. Some sandstone beds contain many faint, dark lines that are arc-shaped and concave upward. These features, often called dish structures (Wentworth, 1967), generally are less than 10 cm (4 cm) from horn to horn. Climbing ripples are present locally near the tops of these beds, which are commonly capped by shale. Amalgamated beds also are present, especially in the middle portion of this unit (fig. 17). Contacts between amalgamated sandstone beds can be subtle or sharp, depending upon the grain size contrast between beds.

The middle part of the section, from 43 to 136 m (141 to 446 ft) above the base of the section (fig. 16), consists of 93 m (305 ft) of interbedded sandstone and shale with a sandstone-to-shale ratio that averages 1:5. Individual sandstone beds typically are fine- to medium-grained, less than 10 cm (4 in) in thickness, and they are mostly assigned to Facies D, E, and G. Because of the large amount of shale that is present throughout this part of the section, exposures are quite poor; however, several exposed sandstone intervals show planar laminations with small-scale cross bedding and climbing-ripple laminations

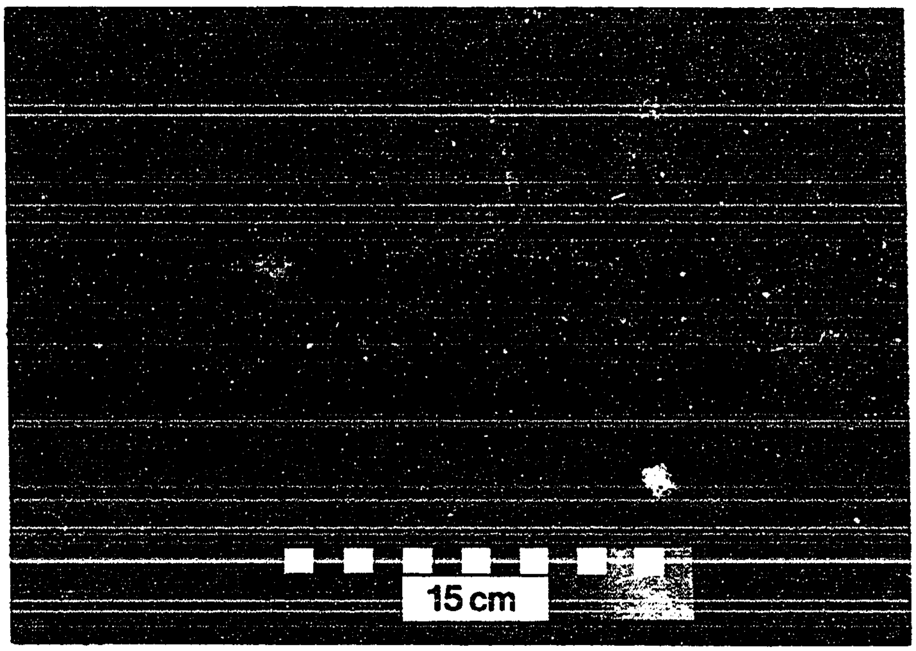


Figure 17. Sharp boundary between amalgamated sandstone beds about 16 m (52 ft) above the base of the Guinda Formation along the South Fork of Willow Creek.

near the top of each bed. Shale caps these beds.

The upper 76 m (249 ft) of the section, beginning 136 m (446 ft) above the base of the section (fig. 16), consists of several additional coarse-grained, conglomeratic sandstone units (fig. 18) separated by thick shale beds and interbeds of shale and sandstone. The conglomerate typically grades irregularly upwards into coarse- to medium-grained sandstone. Pebbles in the conglomerate generally are 1 to 4 cm (0.5 to 1.5 in) in diameter, with a scattering of smaller pebbles and granules throughout the bed. Erosional bedding surfaces and interfingering of the conglomerate with medium- to coarse-grained sandstone are common features of this unit. The lateral extent of these beds appears to be limited to about 15 m (50 ft), although this is largely speculative because alluvium blankets most of the surrounding area. Because these beds are highly resistant to weathering, one would expect to see them cropping out laterally if they were present.

The conglomeratic sandstone sequences commonly are capped by discontinuous shale partings, although several beds are amalgamated. Bedding contacts are variable and either are flat and laterally continuous or are scoured with several centimeters of downcutting. Conglomeratic beds are dominated by coarse-grained, clast-supported conglomerate and matrix-supported pebbly sandstone.

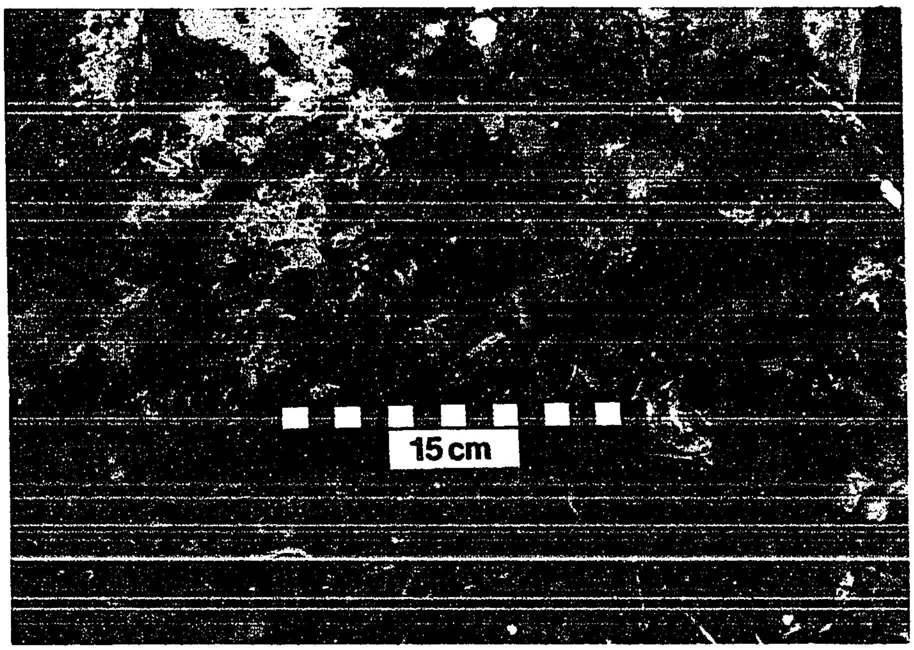


Figure 18. Conglomeratic sandstone beds about 187 m (613 ft) above the base of the Guinda Formation along the South Fork of Willow Creek. Note the orange-colored ferruginous dolomite concretions that are scattered throughout this rock.

Individual beds range from just less than 1 m (3 ft) to more than 2 m (6 ft) in thickness. Individual sedimentary packages range in thickness from less than 2 m (6 ft) to about 9 m (29 ft), with most about 3 m (10 ft) thick.

Interpretation. The lower 43 m (141 ft) of the Guinda Formation is inferred to consist of 9 fining- and thinning-upward middle-fan channel sequences (shown at a reduced scale in Figure 19). Coarse-grained Facies B beds, typical of channel complexes, dominate this part of the section. Dish structures, which suggest post-depositional fluid expulsion, are common in the upper portion of each unit.

The middle portion of the section, from 43 to 136 m (141 to 446 ft) above the base of the section (fig. 19), is assigned to Facies C, D, and G interchannel deposits, although poor exposures make this interpretation somewhat speculative. The thick planar- and ripple-laminated beds suggest Facies C and E crevasse-splay deposits rather than levee deposits, which are normally composed of thinner beds.

The upper part of the measured section, from 136 m (446 ft) above the base of the section (fig. 19), consists of channel and interchannel deposits. The facies D, E, and G interchannel deposits are very similar to those in the middle portion of this measured section. The presence of the Facies A conglomerate suggests deposition in inner- or

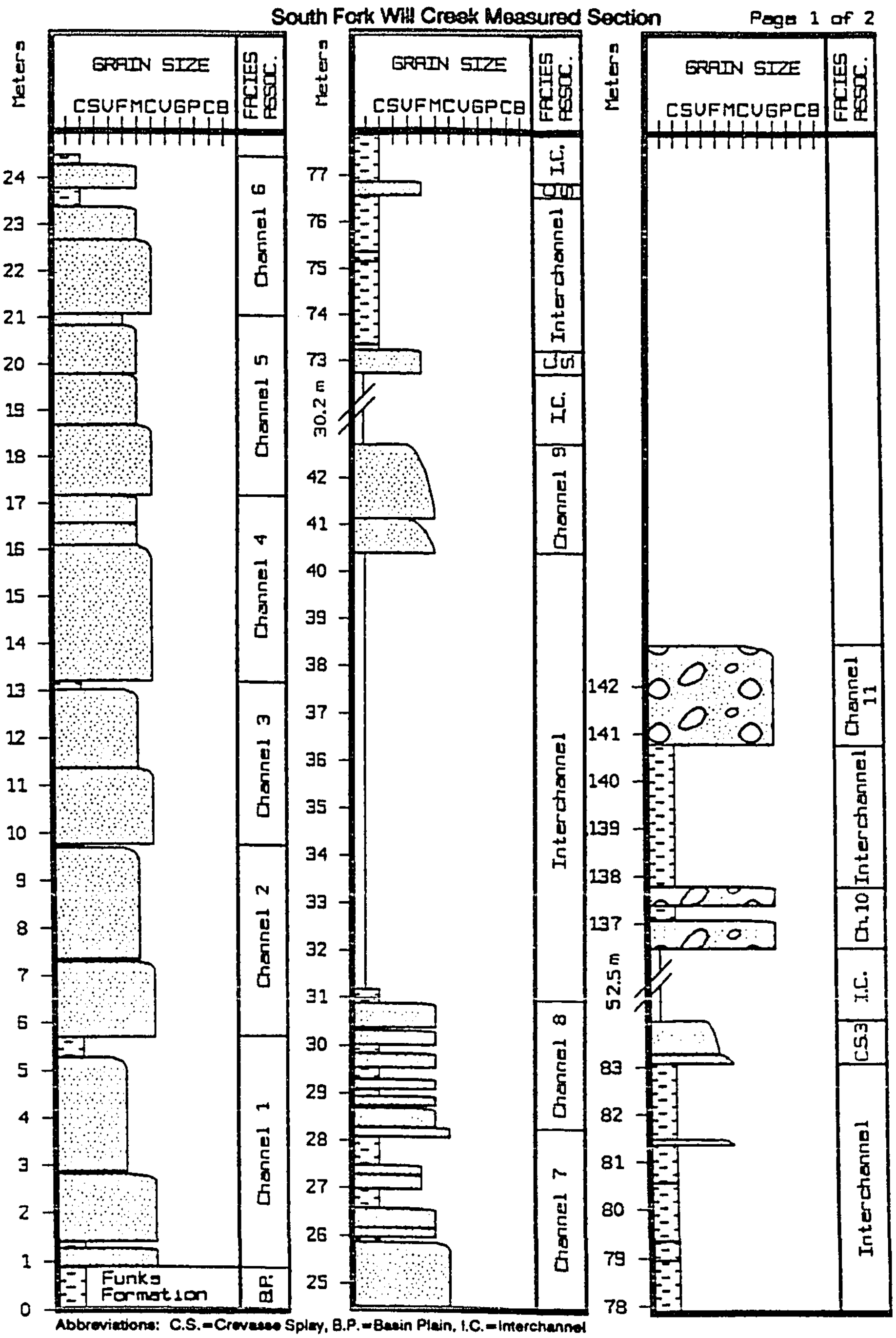


Figure 19. Measured section of the Guinda Formation along the South Fork of Willow Creek, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

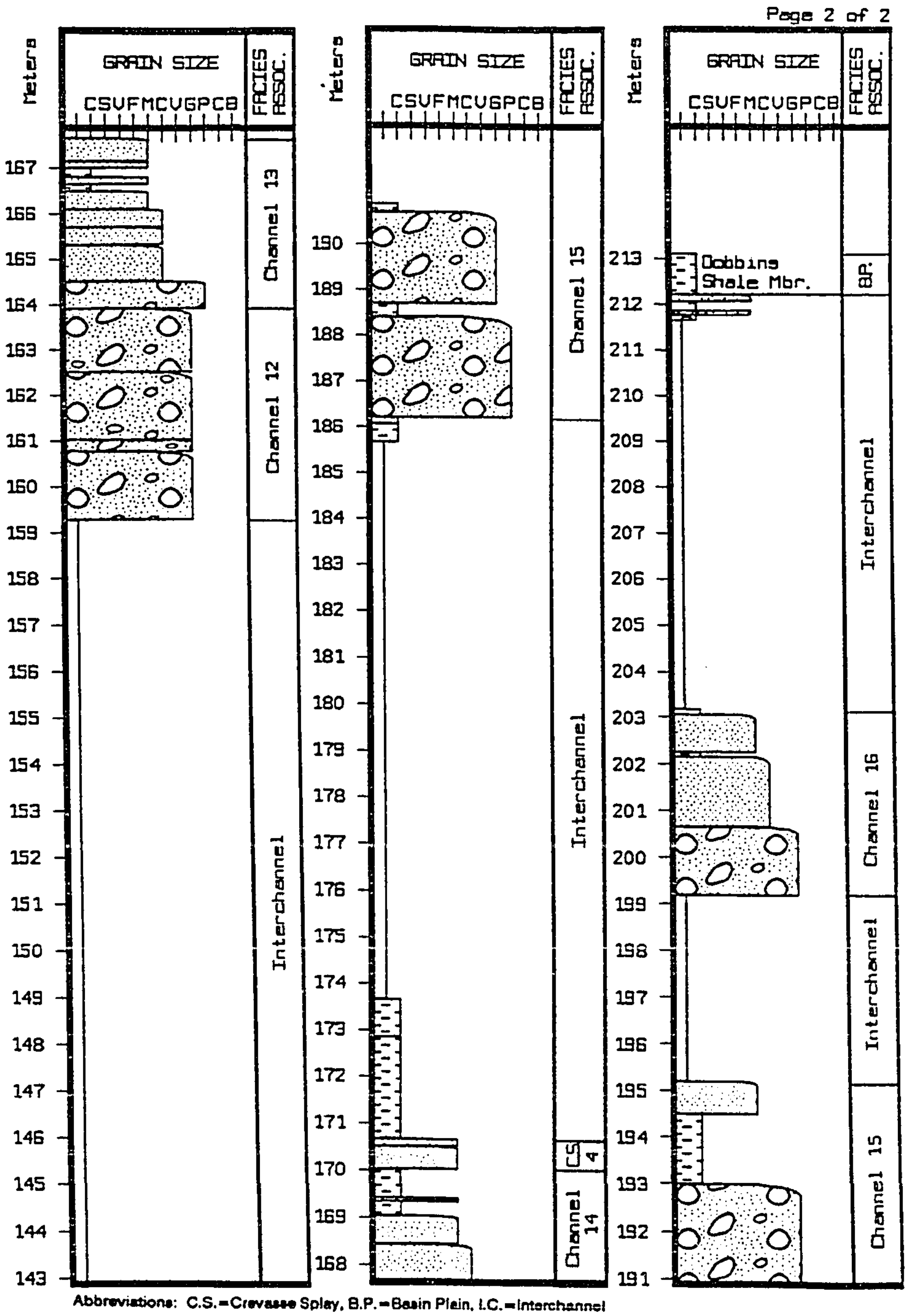


Figure 19 (cont'd).

middle-fan channels, which would be expected in a prograding fan-system. The reason for assigning these channels to a middle-fan rather than an inner-fan environment is that the facies associations represented in adjacent measured sections also indicate middle- and outer-fan environments.

Salt Creek Section

Description. An incomplete section of the Guinda Formation crops out along Salt Creek (SE sec. 33, T.13N., R.3W.), located on the northeastern side of the Capay Hills. Figure 20 is a geologic map of this area. This section is located about 30 km (19 mi) south of the measured section exposed along the South Fork of Willow Creek.

Approximately 50 m (160 ft) of section were measured at this locality, which is shown at a reduced scale in Figure 21. This section is dominated by thick, amalgamated, coarse-grained sandstone beds. Bedding in most of the section is nearly horizontal, but near the top of the section, the beds begin to dip eastward, reaching a little more than 20°. The lower contact with the Funks Formation is concealed at this locality, but the conformable upper contact with the Dobbins Shale is sharp and well exposed.

The Guinda Formation at this locality consists almost

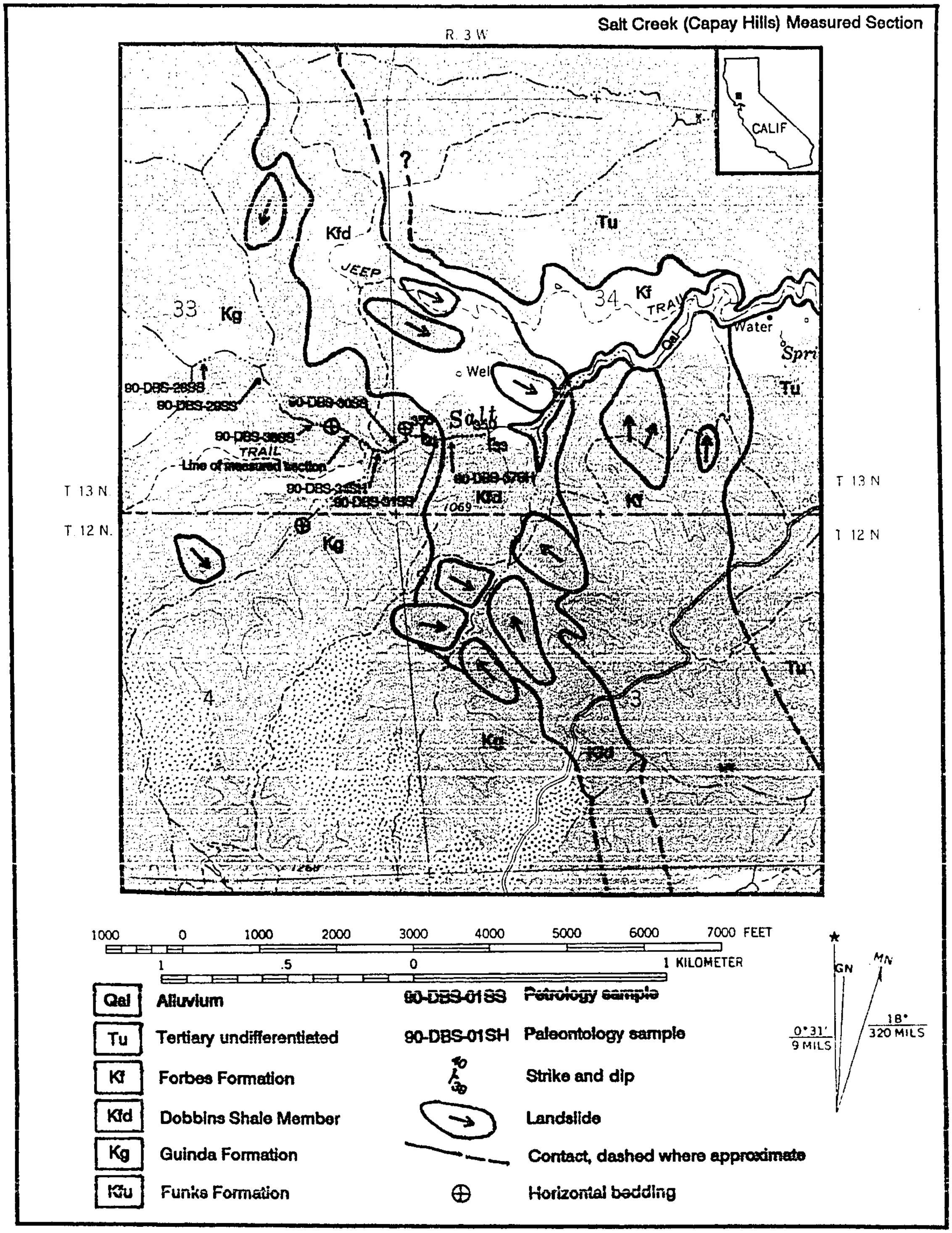


Figure 20. Geologic map of the Salt Creek area (Rumsey 7.5-minute quadrangle).

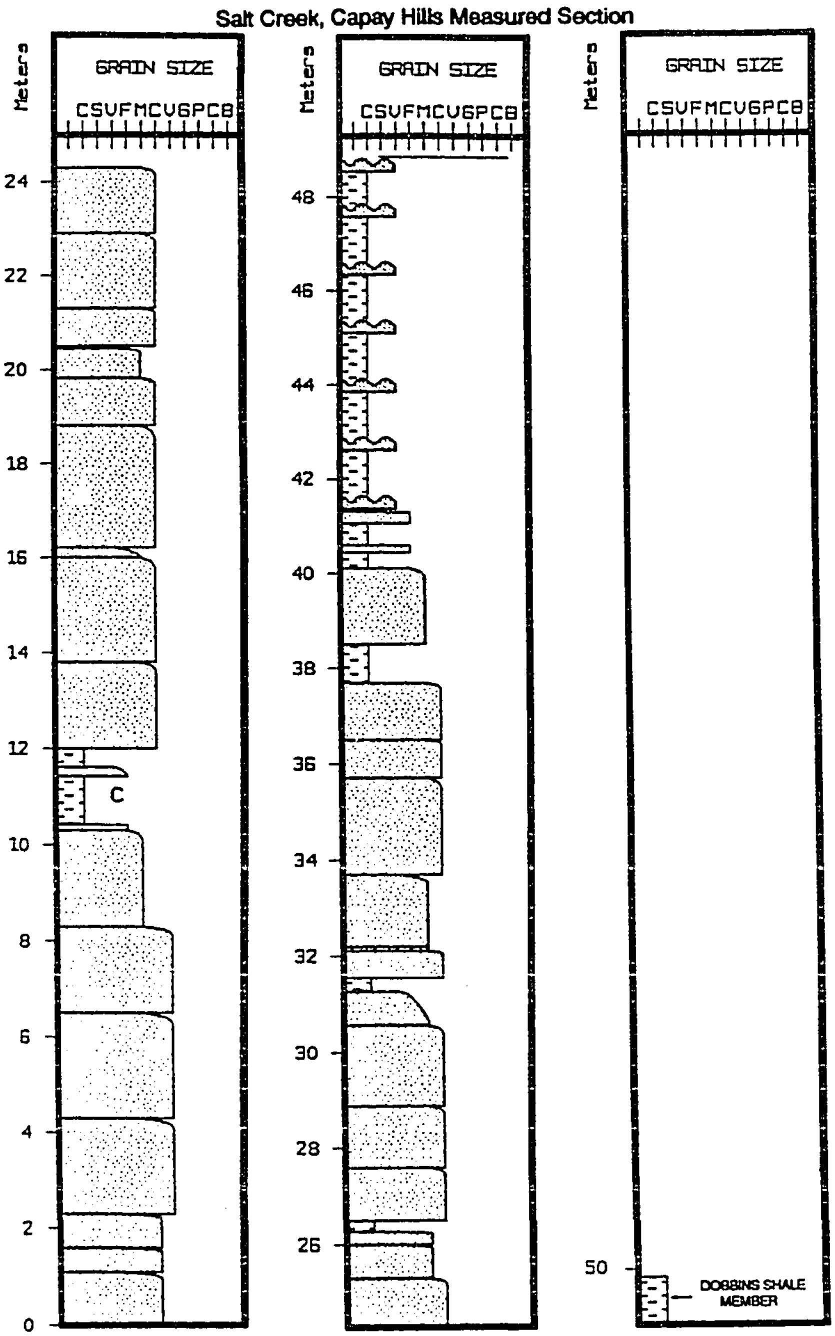


Figure 21. Generalized measured section of the Guinda Formation along Salt Creek in the Capay Hills. See Appendix 1 for the explanation and a detailed outcrop description.

exclusively of stacked, fining-upward sandstone units. In general, the sandstone bodies consist of a sequence of very coarse- to coarse-grained sandstone beds that grade upward into fine-grained sandstones at the top. These sandstone bodies, and the beds that occur within each package, commonly are amalgamated (fig. 22) and are only rarely separated by thin shale partings. The shale beds all are thinner than 1.5 m (5 ft), making this section the most sand rich of all the sections measured by the author.

The sandstone beds are dominantly massive and cross stratified (fig. 23). Scours and channels are common along the bottoms of many beds. Horizontal and ripple laminations are numerous in the upper part of these beds. Many of the sandstone beds also contain many very faint patterns of dark lines that are arc-shaped and concave upward (dish structures). These structures are generally less than 10 cm (4 in) from horn to horn.

A very distinctive feature of the Guinda Formation at this locality is the great number and large size of "cannonball" concretions. In places, the ground is strewn with concretions that range from a few centimeters to 3 m (10 ft) in diameter (fig. 24).

Overlying the lowest 40 m (131 ft) of thick, amalgamated sandstone beds is about 8 m (26 ft) of interbedded sandstone and shale (fig. 21). Near the bottom of this sequence are two prominent beds that consist of

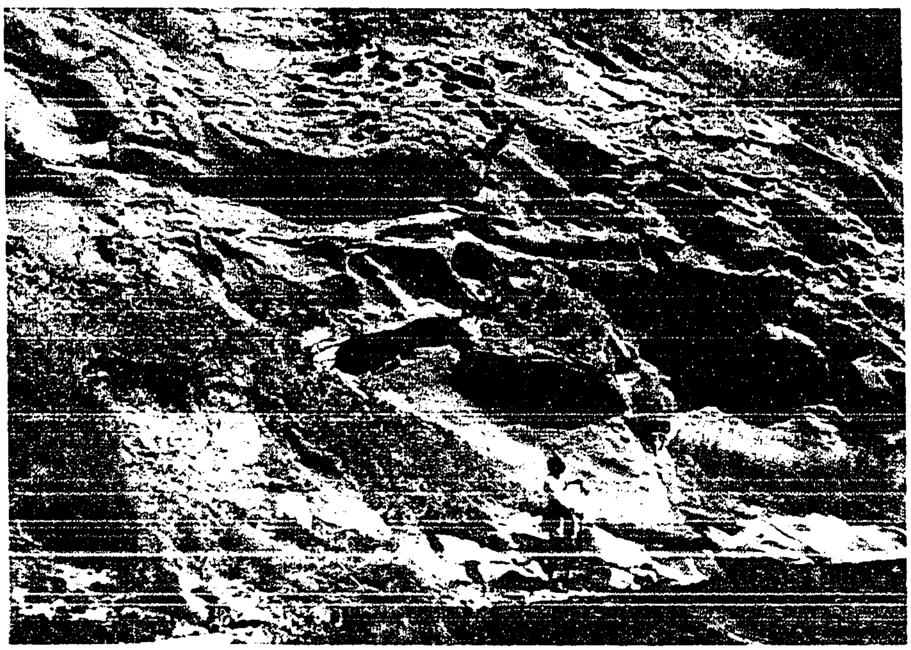


Figure 22. Primarily massive and planar-laminated sandstone beds near the base of the Guinda Formation along Salt Creek in the Capay Hills (1.5-m Jacob's staff for scale).

Figure 23. Cross-stratified sandstone beds offset by a minor fault approximately 16 m (52 ft) above the base of the Guinda Formation along Salt Creek.

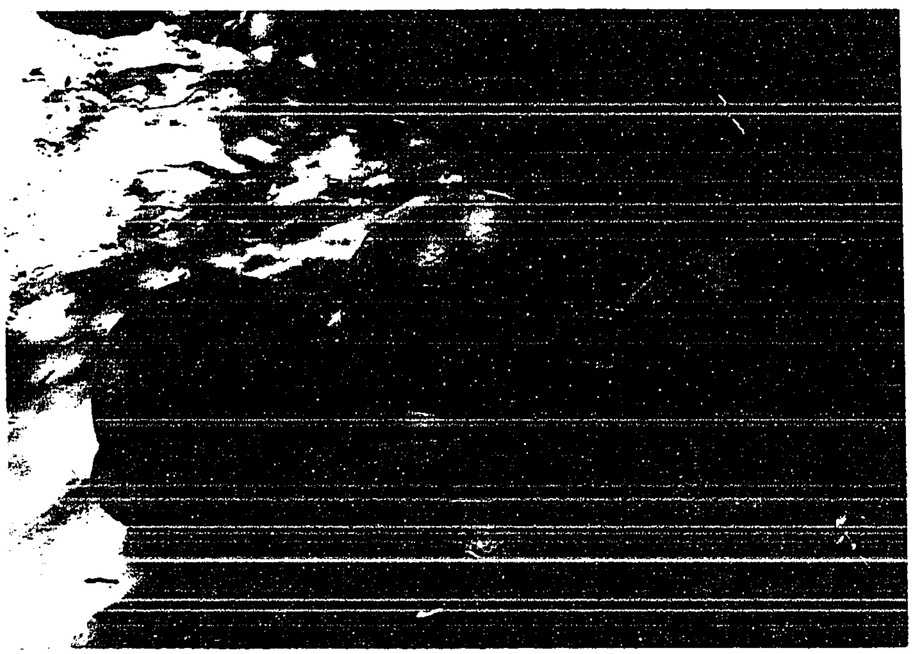


Figure 24. "Cannonball" concretions approximately 16 m (52 ft) above the base of measured section of the Guinda Formation along Salt Creek.

planar-laminated, fine-grained, Facies D sandstone. These beds are assigned to Facies D, E, and G because this part of the section generally consists of very fine- to fine-grained sandstone that is laterally continuous and ripple and convolute bedded, and contains numerous pinch-and-swell features. Also present in this section are scattered Ophiomorpha burrows at the tops of some of the thicker beds. Sandstone-to-shale ratios average about 1:3.

Interpretation. The lower and middle portions of the Guinda Formation, from the bottom of the section to nearly 41 m (135 ft) above the base of the section, have been interpreted as consisting of 23 stacked, Facies B channel sequences (fig. 25). Channel fill is indicated by the presence of scoured bases, cross stratification, and fining- and thinning-upward units. Deposition in the middle-fan environment is suggested by the lack of conglomerate and the presence of other middle-fan facies associations. The high sandstone content (greater than any other measured section) of these rocks may imply deposition in a highly channelized and active part of a fan. Post-depositional fluid expulsion features, such as dish structures, are common in this unit, suggesting that deposition of the sand occurred rapidly.

The uppermost 9 m (30 ft) of the section once consisted of fine-grained sand and mud that accumulated as a result of overbank deposition and settling of very fine

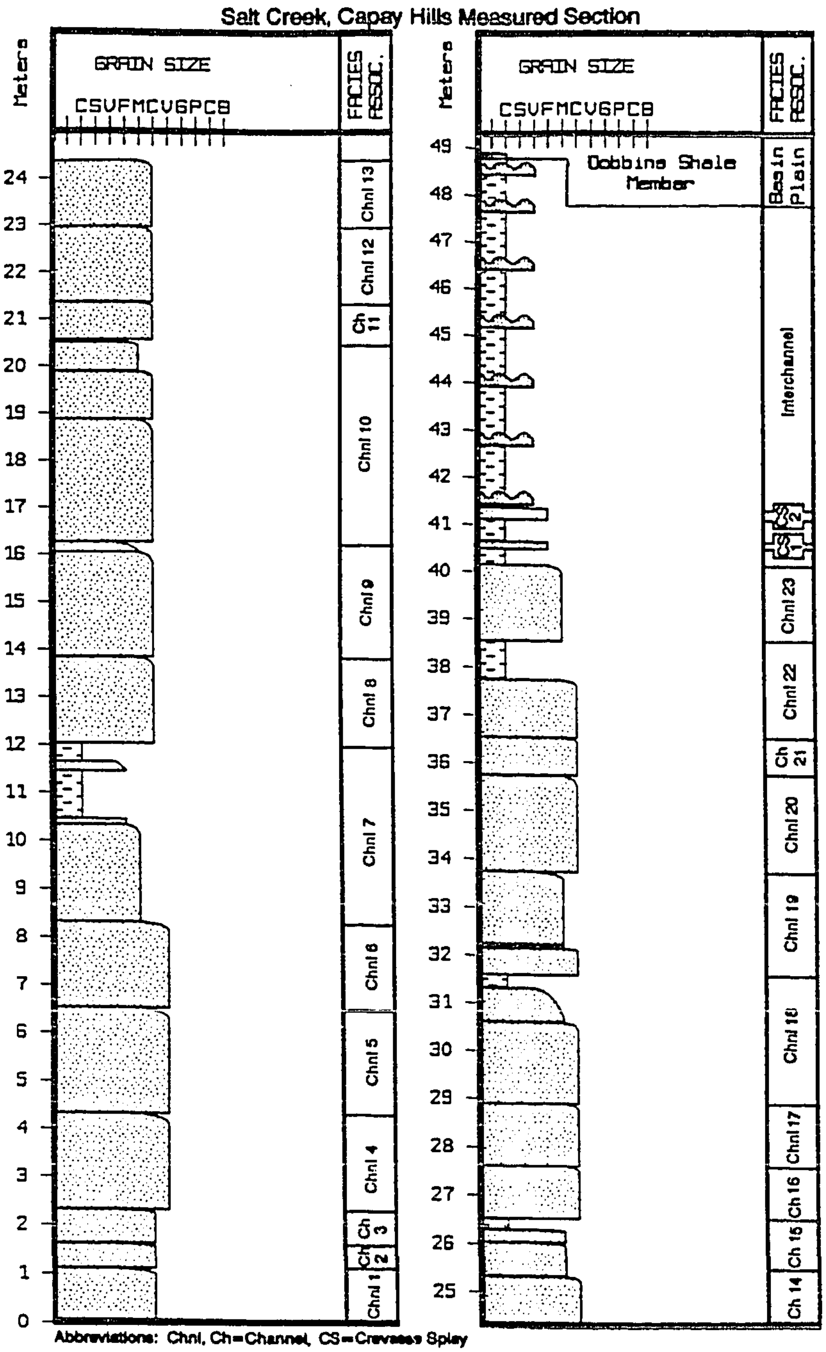


Figure 25. Measured section of the Guinda Formation located along Salt Creek in the Capay Hills, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

material from the water column. Scattered <u>Ophiomorpha</u> burrows and grazing traces at the tops of some of the beds show that deposition was relatively slow. Included in these interchannel deposits are two crevasse splay deposits that consist of fining-upward Facies D sandstone.

Putah Creek/Bray Canyon Section

<u>Description</u>. A complete section of the Guinda Formation is exposed on the north side of Putah Creek, just east of Bray Canyon (SE SE sec. 21, T.8N., R.2W.). This section is located near the southwest corner of Yolo County, approximately 50 km (30 mi) south of the measured section at Salt Creek. Figures 26 is a geologic map of the area.

Nearly 275 m (900 ft) of section, shown at a reduced scale in Figure 27, was measured at this locality. This section is dominated by conglomerate near the top of the section. Dominating the remainder of the section are coarse-grained sandstone beds separated by thick sequences of shale. The beds dip eastward at about 55°, shallowing to about 50° near the top of the section. The contact with the underlying Funks Formation is poorly exposed; the contact with the overlying Dobbins Shale Member of the Forbes Formation is sharp.

The Guinda Formation consists of series of fining- and thinning-upward sandstone sequences (fig. 27). Bed

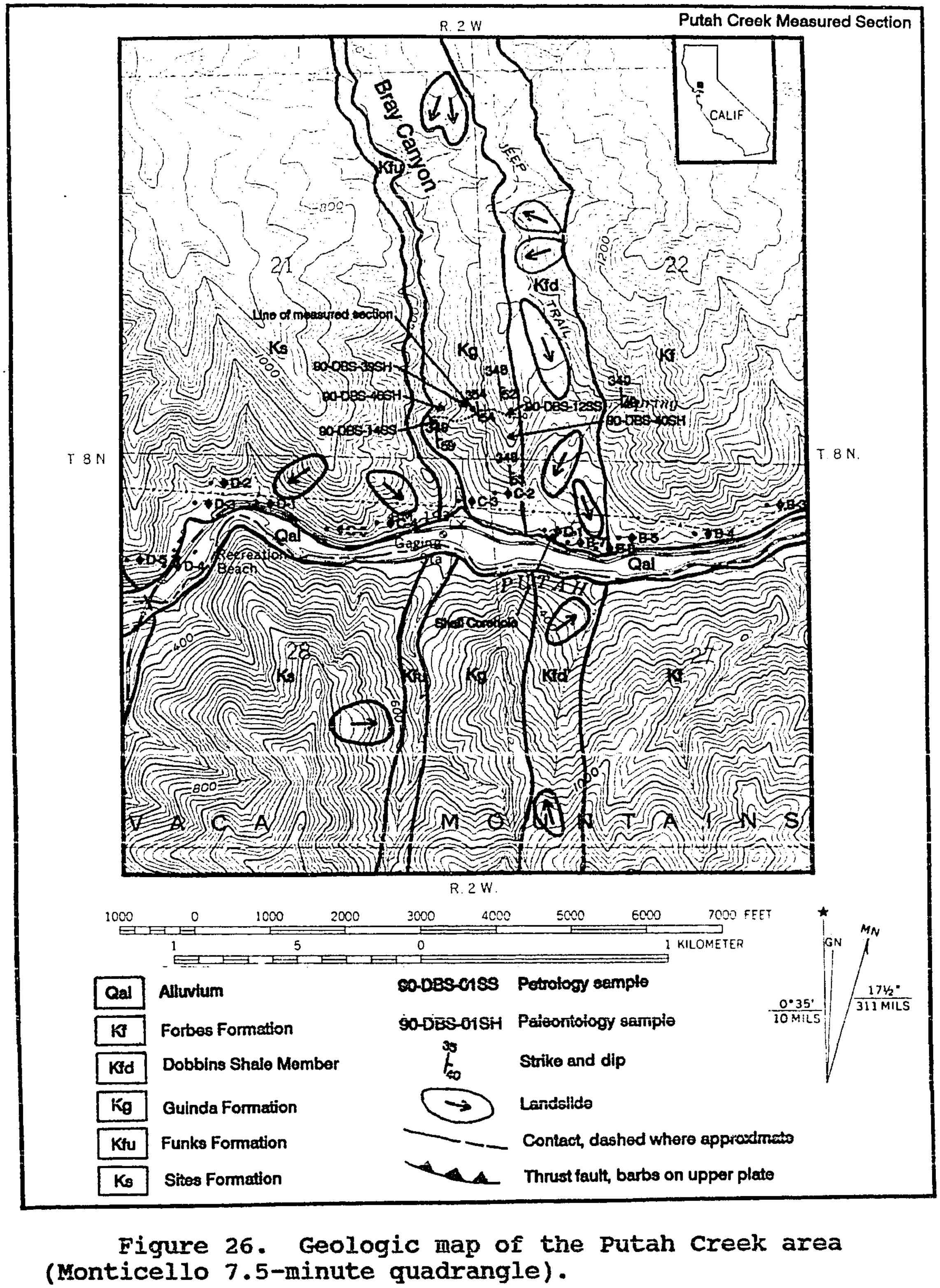


Figure 26. Geologic map of the Putah Creek area (Monticello 7.5-minute quadrangle).

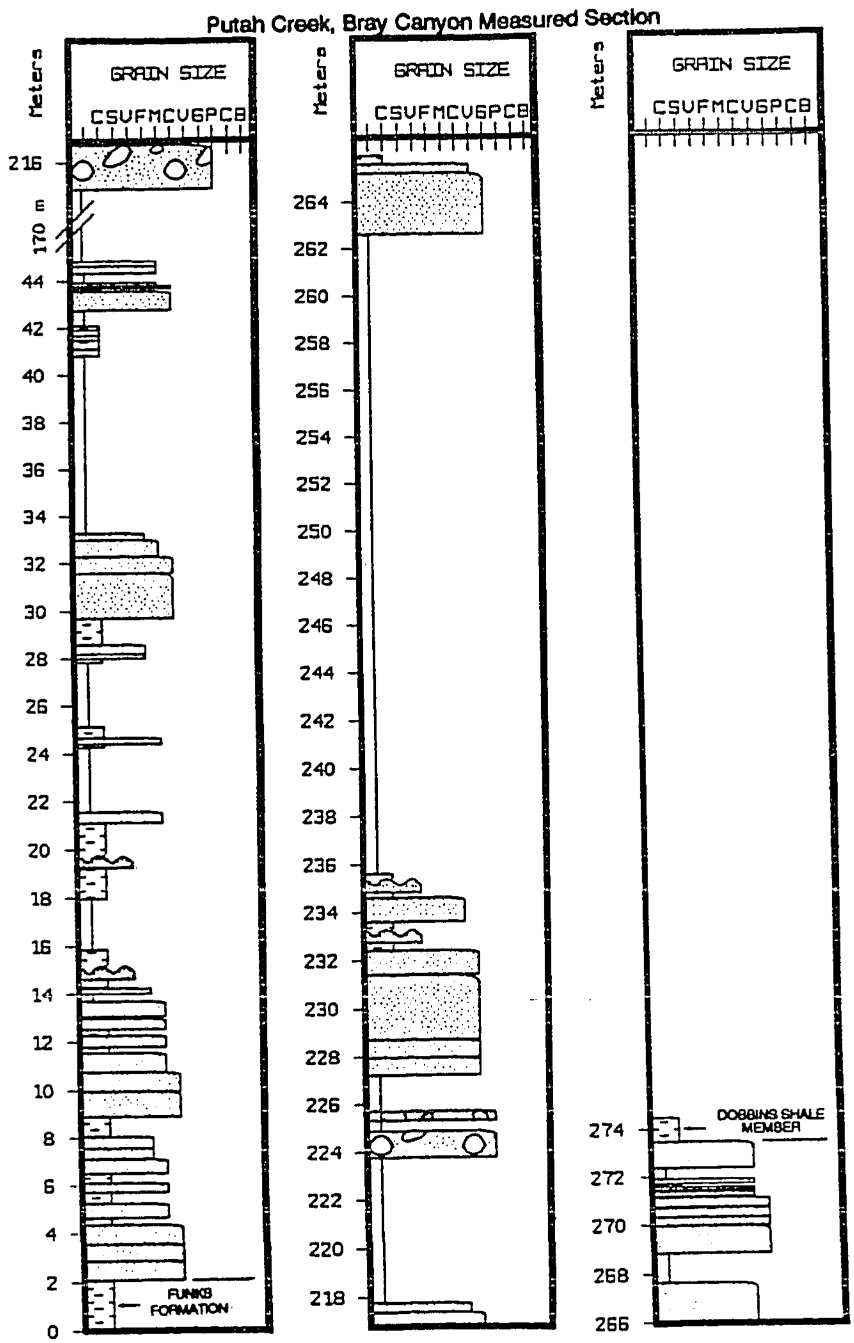


Figure 27. Generalized measured section of the Guinda Formation on the north side of Putah Creek, east of Bray Canyon. See Appendix 1 for the explanation and a detailed outcrop description.

boundaries typically are sharp, although local amalgamation of some beds makes it difficult to determine where one bed ends and the next bed begins. Scouring to depths of 8 cm (3 in) occurs along the bottoms of many sandstone beds. Individual sandstone sequences average about 5 m (16 ft) in thickness.

Facies A pebble and cobble conglomerate forms the base of two sequences located at 215 (705 ft) and 224 m (735 ft) above the base of the section (fig. 28). Beginning about 233 m (764 ft) above the base of the section is a poorly exposed sequence of interbedded sandstone and shale that is approximately 30 m (98 ft) thick (fig. 27). Individual beds within this unit are commonly are less than 6 cm (2 in) in thickness, and sandstone to shale ratios average 1:5. The sandstone beds commonly are laminated with small-scale cross-bedding and climbing ripple laminations near their tops. Some of these beds exhibit pinch-and-swell structures that are laterally discontinuous. Facies D, E, and G beds are common in this unit.

Present at the top of this section, beginning 263 m (863 ft) above the base of the section, is a series of generally fining- and thinning-upward sequences. These sandstone beds generally are massive or planar laminated, commonly with thin shale partings.

Interpretation. The measured section along Bray

Figure 28. Conglomerate from approximately 216 m (709 ft) above the base of the Guinda Formation on the north side of Putah Creek, east of Bray Canyon.

Canyon north of Putah Creek is interpreted as consisting of nine fining- and thinning-upward middle-fan channel sequences (fig. 29). This sequence is dominated by medium- and coarse-grained Facies B beds that commonly exhibit scoured bases, features typical of channels.

The Facies A pebble and cobble conglomerate is believed to have been deposited on the middle fan rather than the inner fan. This is assumed because of the rock's high sandstone-to-shale ratio and its proximity to a distinctive coeval outer-fan facies located only 2.5 km (1.5 mi) south along Alamo Creek in Gates Canyon.

Channel sequences that are not amalgamated commonly are separated by interchannel and levee deposits. The thick interchannel deposits generally consist of fine-grained turbidite sandstones and shale. These turbidites commonly are planar laminated and rippled at their tops and consist mostly of Facies D, E, and G beds.

The best-developed channel levee deposits in any of the measured sections occur approximately 16 m above the base of this section. These beds consist of approximately 8.5 m (28 ft) of poorly exposed, predominantly interbedded shale and sandstone beds assigned to Facies D, E, and G. Individual sandstone beds commonly exhibit abundant climbing ripples, are laterally discontinuous, and form subtle fining-upward sequences. The interbedded shale beds are locally rich in carbonaceous material. The levee

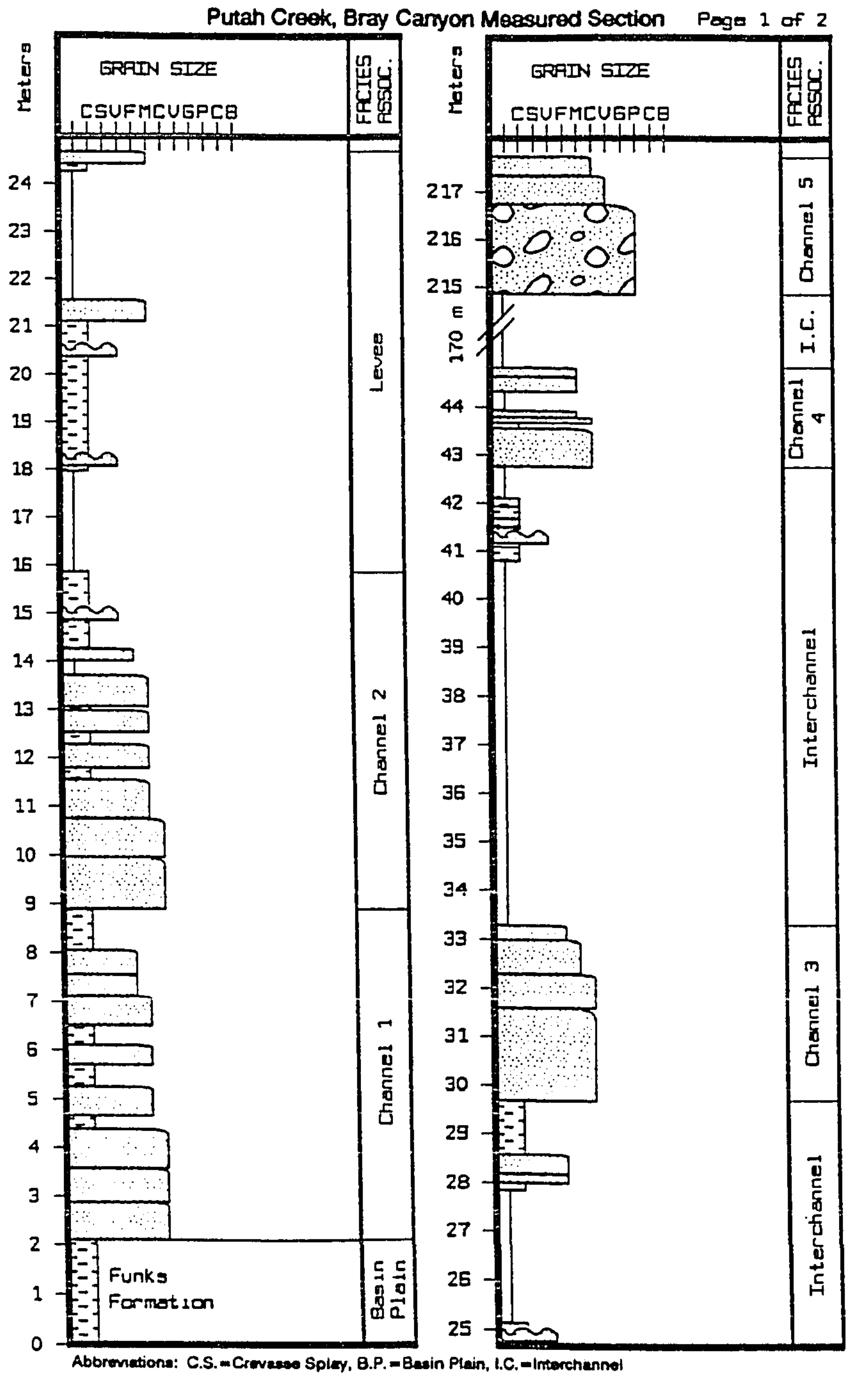


Figure 29. Measured section of the Guinda Formation on the north side of Putah Creek, east of Bray Canyon, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

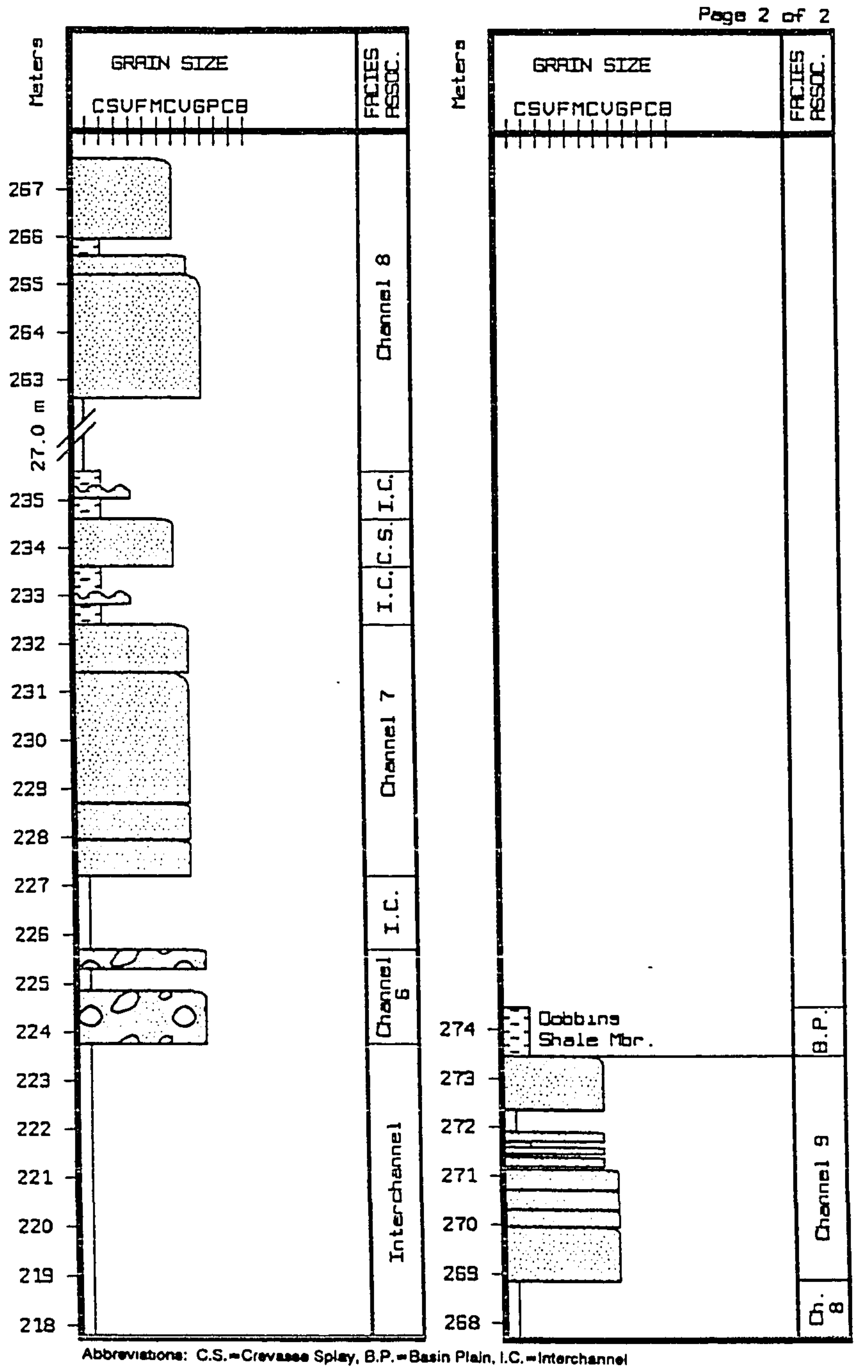


Figure 29 (cont'd).

deposits are distinguished from the interchannel deposits by the presence of thicker, coarser grained sandstone, and the rhythmic interbedding of sandstone and shale.

Ulatis Creek/Mix Canyon Section

Description. An incomplete section of the Guinda Formation crops out along Ulatis Creek in Mix Canyon (NW SW sec. 34, T.7N, R.2W.) in northwestern Solano County. This outcrop is located about 12 km (7 mi) south of the Putah Creek measured section. Figure 30 is a geologic map of the area.

Approximately 15 m (50 ft) of the Guinda Formation is exposed at this locality, which has given the illusion to several workers that this formation pinches out in this area (Emerson and Roberts, 1962; Nilsen, 1990). Close inspection of the regional and local geology, however, reveals that the Guinda Formation has been locally folded and faulted. The entire Funks Formation and probably a substantial portion of the Guinda Formation have been faulted out at this locality. The subjacent Sites Formation and superjacent Dobbins Shale Member of the Forbes Formation both dip about 50° eastward, whereas the Guinda Formation in this area is essentially horizontal, demonstrating the local structural complications.

The section measured in Mix Canyon is shown at a reduced scale in Figure 31. These rocks consist of several

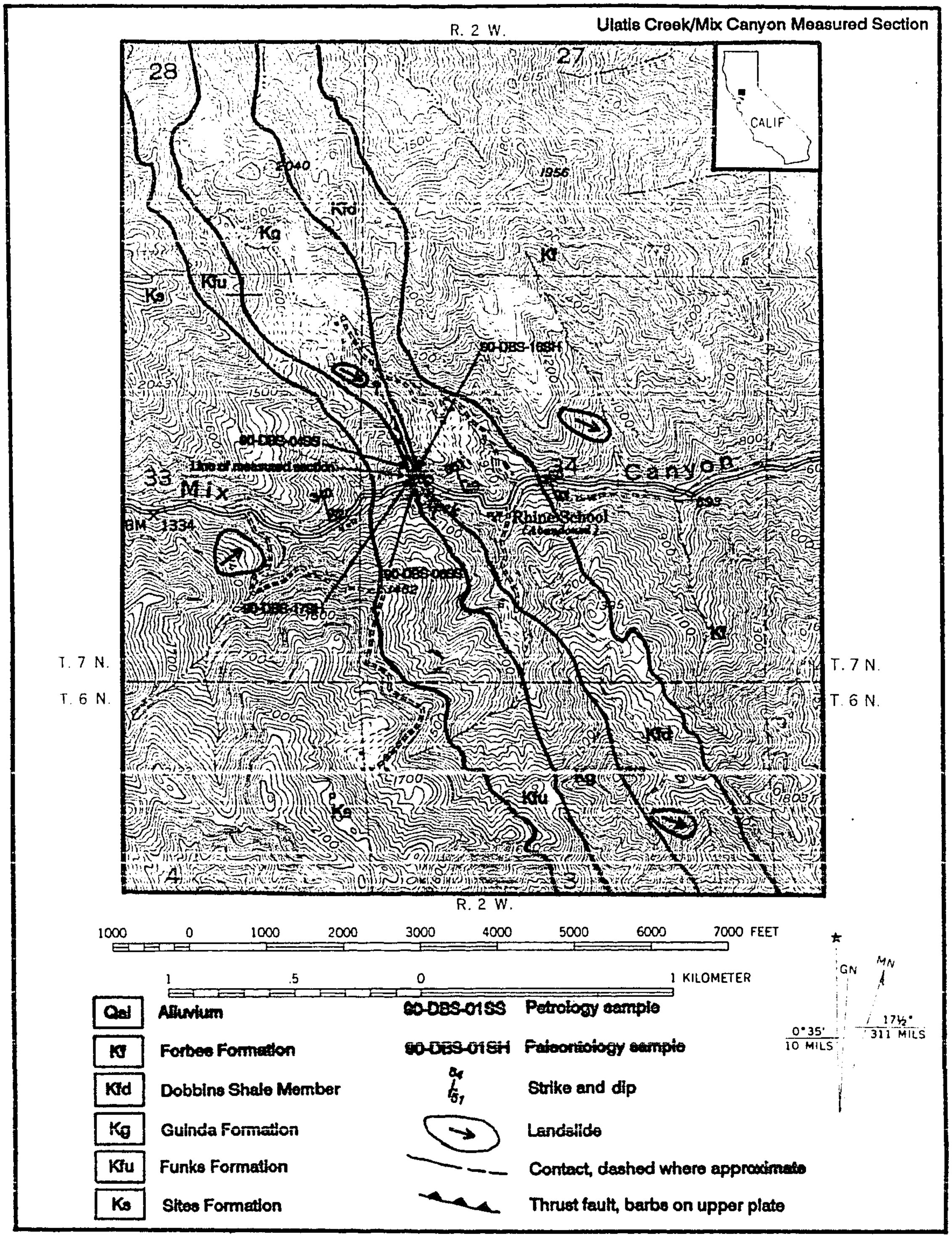


Figure 30. Geologic map of the Mix Canyon area (Mt. Vaca 7.5-minute quadrangle).

Ulatis Creek, Mix Canyon Measured Section

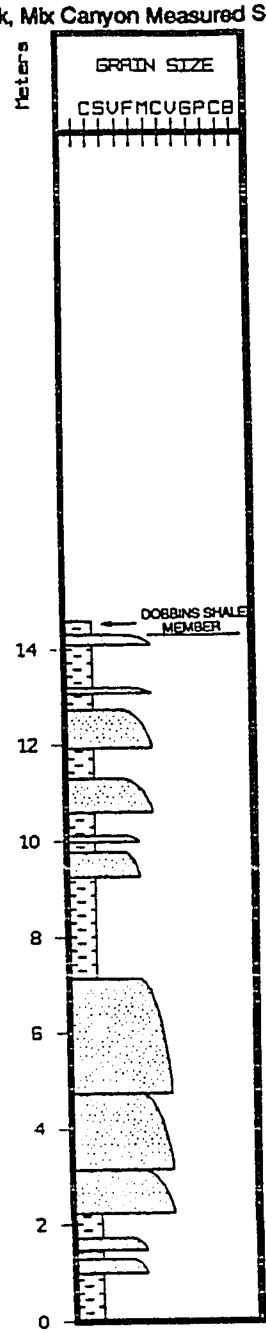


Figure 31. Generalized measured section of the Guinda Formation along the north side of Ulatis Creek in Mix Canyon. See Appendix 1 for the explanation and a detailed outcrop description.

amalgamated Facies B sandstone sequences. Bedding within these units are generally planar, and each sequence averages about 2 m (6 ft) in thickness (fig. 31). Because the rock in this section is highly fractured and grain size is uniform, it is possible that there may actually be additional sandstone packages present. The lower contacts of some of these beds are irregular and display as much as 16 cm (6 in) of downcutting.

Above and below the amalgamated sandstone sequence (fig. 32) are interbeds of sandstone and shale of Facies E and G. The average sandstone-to-shale ratio of these beds is 1:6. Intermixed with these rocks are thicker beds of fine- to medium-grained sandstone of Facies C and D that impart a distinct non-rhythmic nature to these turbidites. These beds commonly are planar-laminated and rippled at their tops. Abundant carbonaceous material/charcoal is present in the shale. The top of this unit grades into the overlying Dobbins Shale Member of the Forbes Formation, which contains abundant calcareous concretions.

Interpretation. The Guinda Formation exposed along Mix Canyon is difficult to interpret due to the local structural complexities. Three fining-upward and amalgamated channel sequences are present in these rocks (fig. 33). The basal contact of these channels are erosional. Interbedded sandstone and shale beds located

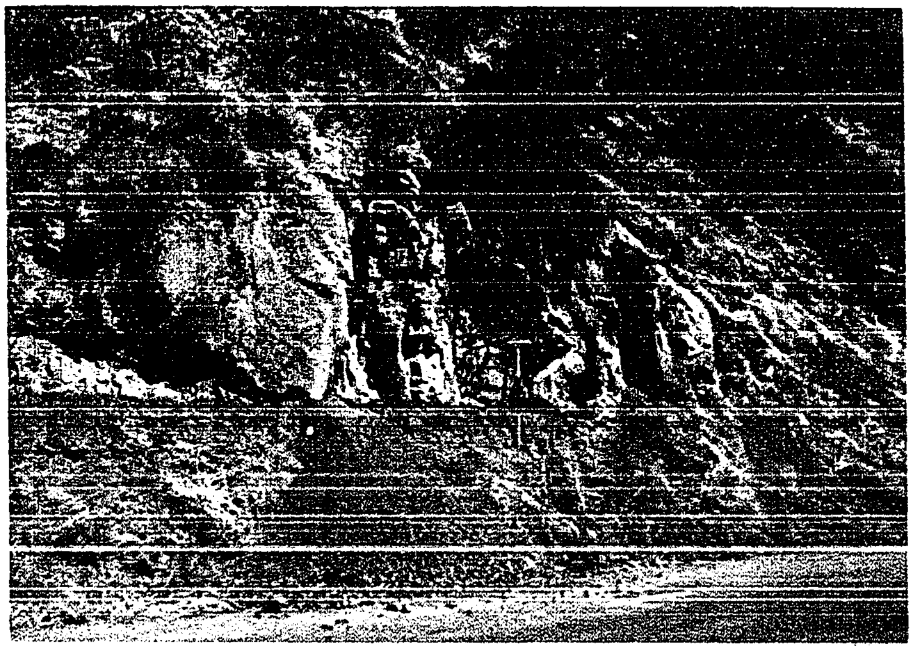


Figure 32. Thick, amalgamated, massive and planar-laminated sandstone beds near the top of the Guinda Formation along the north side of Ulatis Creek in Mix Canyon. Interbedded sandstone and shale lie below and above the massive sandstone sequence. A 1.5-m Jacob's staff is located just to the right of the center of the photograph.

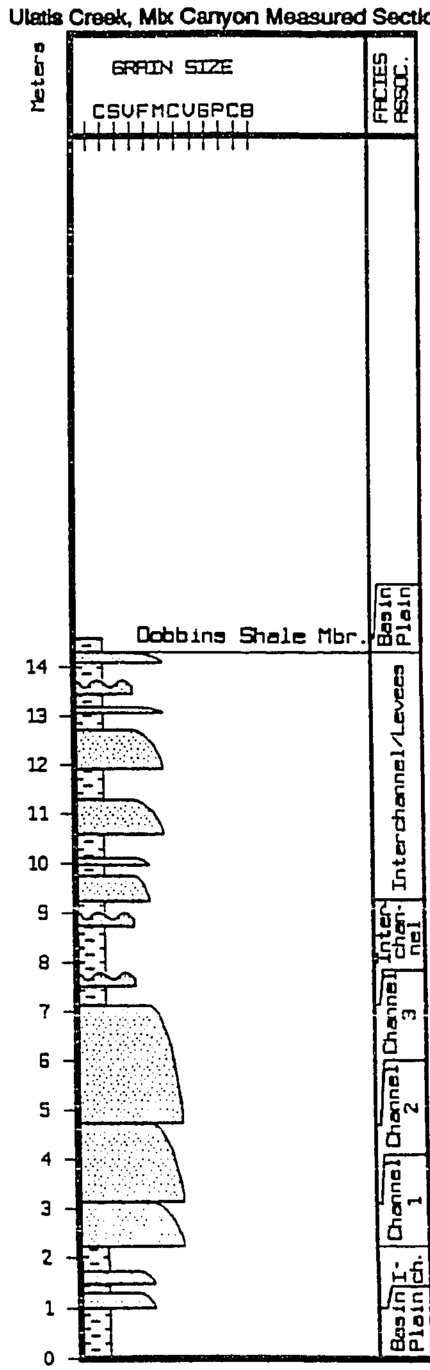


Figure 33. Measured section of the Guinda Formation along the north side of Ulatis Creek in Mix Canyon, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

immediately below this sequence of rocks are interpreted to be interchannel deposits. The thick sandstone beds within the interchannel deposits may be related to small overbank events, but poor exposure makes them difficult to interpret.

Approximately 7 m (23 ft) above the base of the section lie interchannel and levee deposits. Although poorly exposed, the thicker and coarser-grained sandstone beds contained in this unit are believed to be levee deposits because they flank the channel deposits, have sharp basal contacts, have a high ratio of sandstone to shale, and exhibit poorly graded tops that are commonly rippled.

Alamo Creek/Gates Canyon Section

Description. A complete and well exposed section of the Guinda Formation crops out along Alamo Creek in Gates Canyon (SE SE sec. 3, T.6N., R.2W.), in northwestern Solano County. Figure 34 is a geologic map of the area. The measured section is located about 2.5 km (1.5 mi) south of the measured section at Mix Canyon. This is the most southerly exposure of the Guinda Formation along the western margin of the Sacramento Valley. The best exposures are located along the banks and in the bed of Alamo Creek; thus, this section is best observed during times of low water.

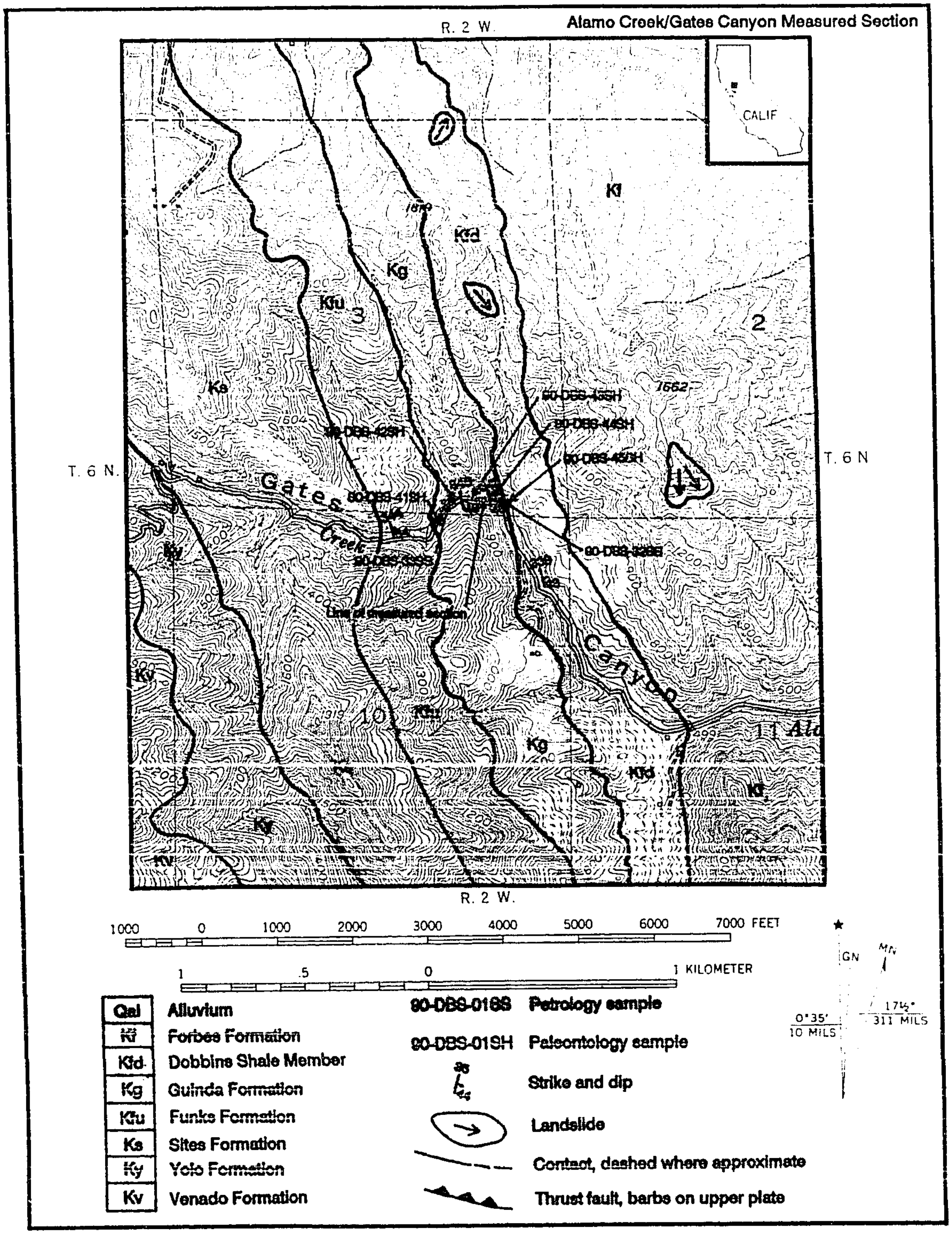


Figure 34. Geologic map of the Gates Canyon area (Mt. Vaca 7.5-minute quadrangle).

Approximately 216 m (709 ft) of the Guinda Formation is present at this locality. This measured section is shown at a reduced scale in Figure 35. These rocks are dominated by medium- to coarse-grained sandstone, interbedded sandstone and shale, and thick sequences of shale. Beds dip eastward at approximately 50°. Contacts with the Funks Formation and the Dobbins Shale Member of the Forbes Formation are well exposed and sharp.

Two sandstone-rich, thickening- and coarsening-upward sequences, beginning 30 m (98 ft) above the base of the section, overlie the shaly unit (fig. 35). The lower sequence is about 4 m (9 ft) thick, and is separated from the upper sequence by about 27 m (88 ft) of shale. The upper sequence is about 8 m (26 ft) thick. The beds that make up these units are dominated by coarse-grained, massive and planar bedded Facies B, C, and D sandstones that commonly have thin shale breaks between adjacent beds, although some beds are amalgamated. The basal bedding contacts are commonly irregular, and rare shale rip-up clasts occur near the bases of some beds. Flute casts and rare sole markings occur along the basal contacts of some of the sandstone beds.

Overlying these deposits, beginning at about 71 m (233 ft) above the base of the section (fig. 35), is about 40 m (131 ft) of interbedded sandstone and poorly exposed shale. The tops of individual sandstone beds commonly are rippled

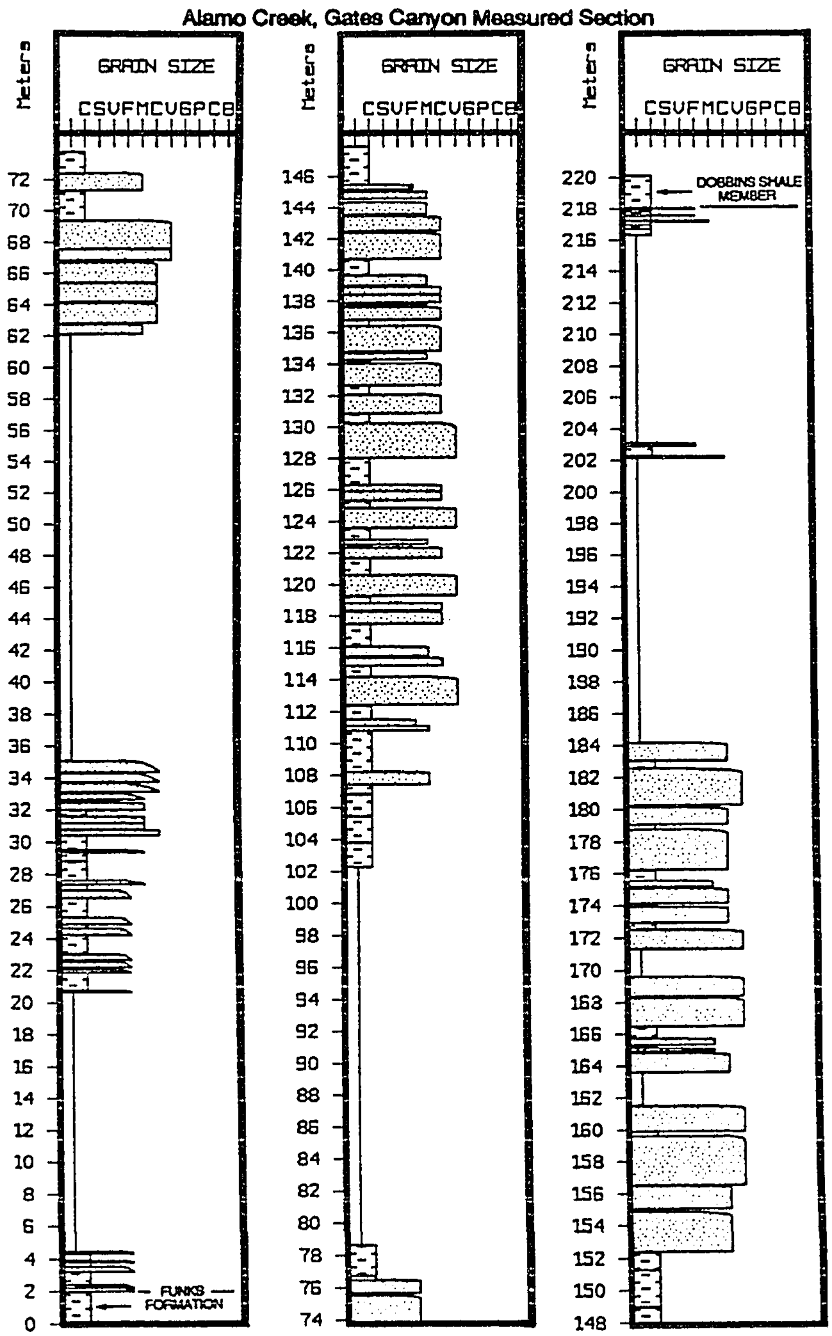


Figure 35. Generalized measured section of the Guinda Formation along Alamo Creek in Gates Canyon. See Appendix 1 for the explanation and a detailed outcrop description.

or have wavy laminae. This interval consists mainly of Facies D, E, and G beds, with sandstone-to-shale ratios in the Facies E beds averaging 1:7. Large bedding convolutions up to 25 cm (10 in) from base to top occur in this section. Pinch and swell features are commonly located near the tops of thin shale beds. Flame structures also are present. Topping this interval is approximately 33 m (108 ft) of poorly exposed shale and thin-bedded sandstone.

Approximately 72 m (236 ft) of primarily massive- and planar-bedded, medium-grained sandstone crops out from 112 to 184 m (367 to 604 ft) above the base of the section (fig. 35). These sandstone packages generally consist of fining- and thinning-upward sequences, and individually range in thickness from 1 to 3 m (10 to 33 ft). Basal bedding contacts commonly are irregular, display downcutting, and locally are scoured; adjacent sandstone beds commonly are separated by thin shale beds, but a few beds are amalgamated. Sandstone is almost exclusively medium to coarse grained, and generally is massive and planar bedded. Rare ripple laminations and convolute bedding occur at the tops of these beds.

Overlying the thick sequence of fining-upward sandstone beds, beginning 184 m (604 ft) above the base of the section, are about 34 m (112 ft) of poorly exposed shale and thin-bedded, fine-grained sandstone beds that are separated in a few places by more massive medium- to coarse-grained sandstone beds. These thin sandstone beds generally are less than 1 m (3 ft) in thickness (fig. 35). The poorly exposed sequence has sandstone-to-shale ratios that average 1:5. Many of these sandstone beds are planar laminated and rippled at their tops. The top of the section is overlain by Facies G deposits of the Dobbins Shale Member of the Forbes Formation.

Interpretation. A wide range of deep-sea-fan facies are present in this section. Figure 36 is the interpreted facies associations of this section. Overlying the basin plain Facies G beds of the Funks Formation is a thick sequence of primarily Facies G and E fan-fringe deposits. The thin, interbedded fine-grained sandstone and shale beds thicken upward and suggest that deposition was controlled in the same manner that produced the sandstone lobes. These fan-fringe deposits represent the most distal part of a fan system that is actively prograding over the fairly flat basin plain.

Two outer-fan depositional-lobes, each of which is separated by poorly exposed, shale-rich, interlobe deposits, prograded over the fan-fringe deposits (fig. 36). These nonchannelized deposits are characterized by thickening- and coarsening-upward sequences characteristic of Facies B, C and D.

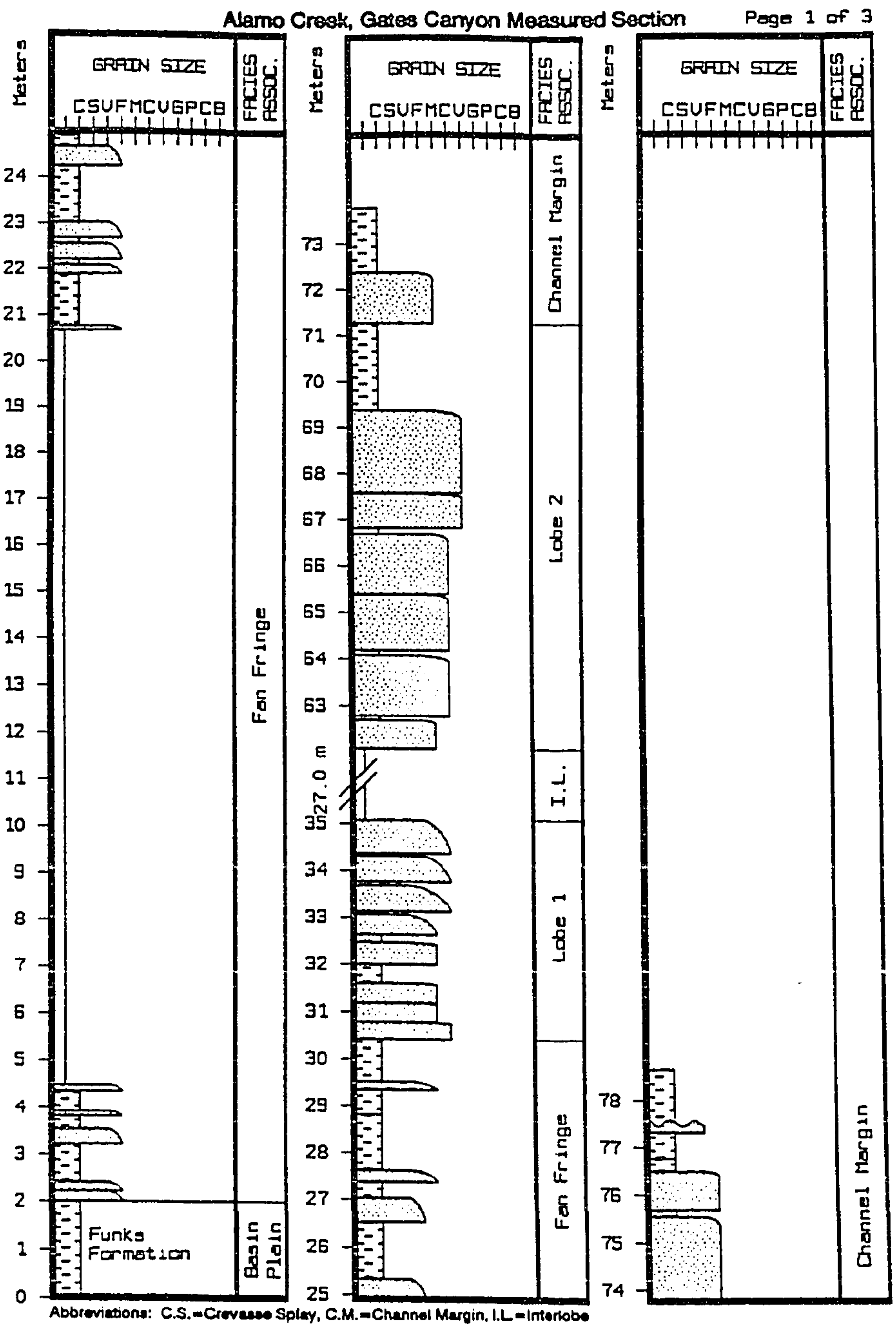


Figure 36. Measured section of the Guinda Formation along Alamo Creek in Gates Canyon, with interpreted facies associations. See Appendix 1 for the explanation and a detailed outcrop description.

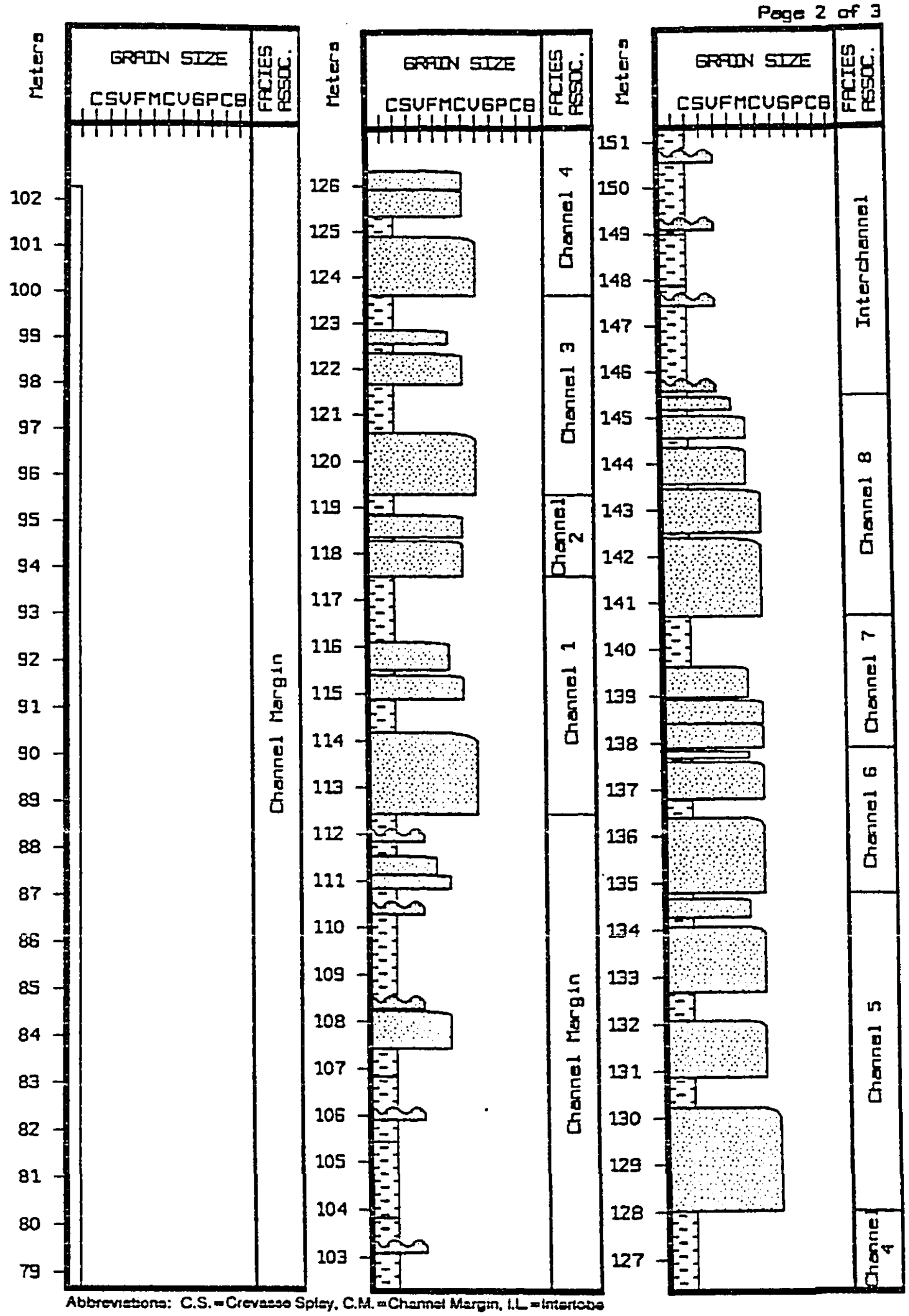


Figure 36 (cont'd).

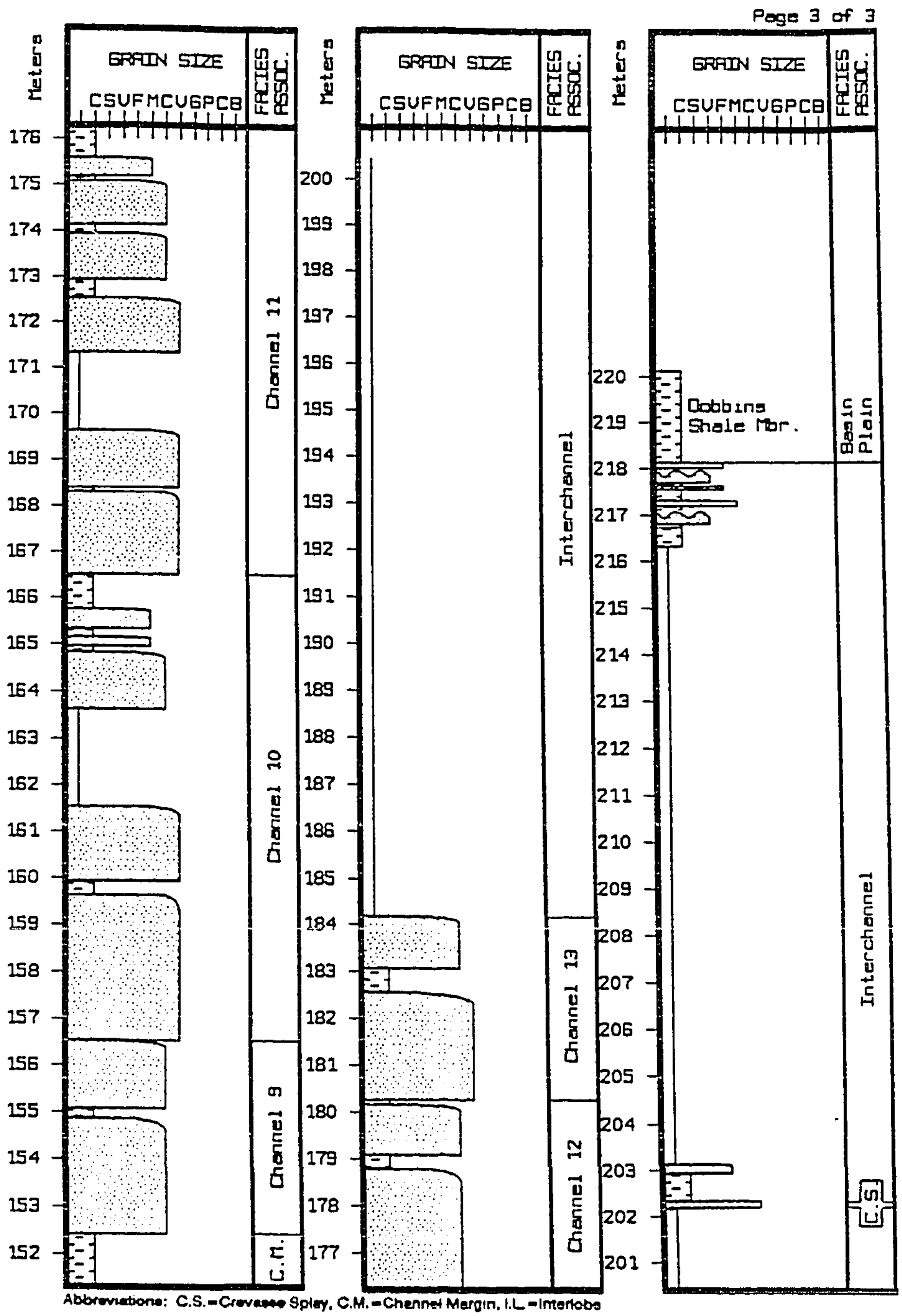


Figure 36 (cont'd).

The convolute beds are very similar to those at Black Butte Reservoir. These features probably were formed as the result of soft-sediment deformation. Flame structures are due to loading of the overlying sediment causing thin wisps of clay and silt to be extruded upward. Shale rip-up clasts indicate that turbidity currents were strong enough to cause parts of the substratum to become detached. The large convolute beds, shale rip-up clasts, and the presence of flame structures indicate that deposition was rapid.

Overlying the lobe deposits, beginning 71 m (233 ft) above the base of the section, are about 41 m (135 ft) of primarily Facies D, E and G channel margin deposits consisting of poorly exposed shale and interbedded shale and sandstone. Numerous small sandstone bodies within this unit represent small turbidity currents or overbank deposition from nearby channels.

Thirteen middle-fan channel deposits, beginning about 112 m (367 ft) above the base of the section, directly overlie the channel margin deposits. Each channel consists almost exclusively of Facies B and G beds that fine and thin upward from coarse-grained sandstone to medium- and fine-grained sandstone. Prograding over the channels are interchannel deposits that are separated in places by coarse-grained crevasse-splay deposits. Cessation of deposition of the Guinda prograding fan system is marked by the accumulation of hemipelagic muds onto the basin plain, which now form the Dobbins Shale Member of the Forbes Formation.

Description and Interpretation of Core

Introduction

The California Well Sample Repository has cataloged cores from 15 wells that contain samples from the Guinda Formation (California State College, Bakersfield, 1986). Table 1 lists these wells. Of these 15 cores, only two are continuous cores; the remaining samples consist of either well cuttings or core chips. The fragments from core chips generally are larger than fragments derived from ditch samples, but neither are particularly well-suited for stratigraphic analysis.

The two continuous cores cut through the Guinda Formation were part of a detailed microfossil and lithologic sampling program conducted in 1951 by Shell Oil Company along Putah Creek (Stinemeyer, 1979). Over 30 outcrop-stratigraphic diamond-drill coreholes, which represent over 4725 m (15,500 ft) of stratigraphic section through nearly the entire Upper Cretaceous, were drilled for this program. Because the purpose of the coring program was to resolve conflicting stratigraphic correlation problems in the immediate vicinity, each core was drilled perpendicular to bedding in order to get a true representation of the stratigraphic profile (E.H.

Stinemeyer, oral comm., 1990). For each core, Shell made lithologic descriptions, sampled for microfossils, and had thin sections cut for petrographic analysis. Unfortunately, many of Shell's initial core descriptions and all laboratory results are no longer archived or accessible for review (R.H. Robinson, oral comm., 1990). Twenty-nine of these cores are available for examination at the Repository, although most are of poor quality because of their age and destruction due to previous petrographic and paleontologic sampling.

The cores from Shell Oil Company's Putah Creek Section C Diamond No. 1 and No. 2 wells (NW NW sec. 27, T.8N., R.2W.) provide a partial section of the Guinda Formation. Benthic foraminifera and nannofossils suggest that the formational boundary between the Guinda Formation and Forbes Formation lies at the sandstone/shale contact near the top of the core (as reported by UNOCAL Corp., in Trosper (1985)). Unfortunately, no well logs were run in these coreholes, so that the cores can not be compared to their corresponding log signatures.

Putah Creek Section C Diamond No. 1 Core

The Putah Creek Section C Diamond No. 1 core was described for this report and is shown at a reduced scale in Figure 37. Appendix 2 contains a detailed bed-by-bed description of this core.

Table 1

Well Samples from the Guinda Formation Stored at the California Well Sample Repository

WELL NAME	OPERATOR	LOCATION	RECOVERED INTERVAL (ft)	SAMPLE TYPE
Glenn Community No. 3-72-20	Superior Oil Company	31-21N-1W	3511- 9179	Cuttings
Benamate No. 2	Texaco, USA	4-19N-2W	7034- 7079	Cuttings
Browning No. 2	Occidental, USA	20-16N-1E	40- 8097	Ditch
Arbuckle Road No. 8	Chevron, USA	20-15N-1E	3280- 9000	Ditch
Arbuckle Road No. 7	Chevron, USA	20-15N-1E	3090- 9100	Ditch
Alexander No. 1	Union Oil Company-W.G.	34-14N-2E	3860- 6920	Ditch
Sutter Basin No. 34-1	Mohawk Oil Company	34-14N-2E	6280- 7715	Ditch
College City No. 5	Coastal Oil & Gas Corp.	36-14N-1W	3280- 9490	Ditch
College City No. 2 (redrill)	Coastal Oil & Gas Corp.	26-14N-1W	7850- 9620	Ditch
Phillips Munnell No. 1-15	Great Basins Petroleum	10-13N-2W	6630- 7325	Ditch
Magoon Estates No. 1	Drilling Exploration	5-12N-3E	1488- 7631	Ditch
Nicolaus Unit	U.S. Geological Survey	2-12N-3E	2000- 8500	Ditch
Putah Ck. Sec. C Dmd. No. 2	Shell Oil Company	27- 8N-2W	47- 653	Core
Putah Ck. Sec. C Dmd. No. 1	Shell Oil Company	27- 8N-2W	60- 456	Core
Chevron Emigh No. 1-2	Channel Exploration	2- 4N-1E	2000-13,020	Ditch

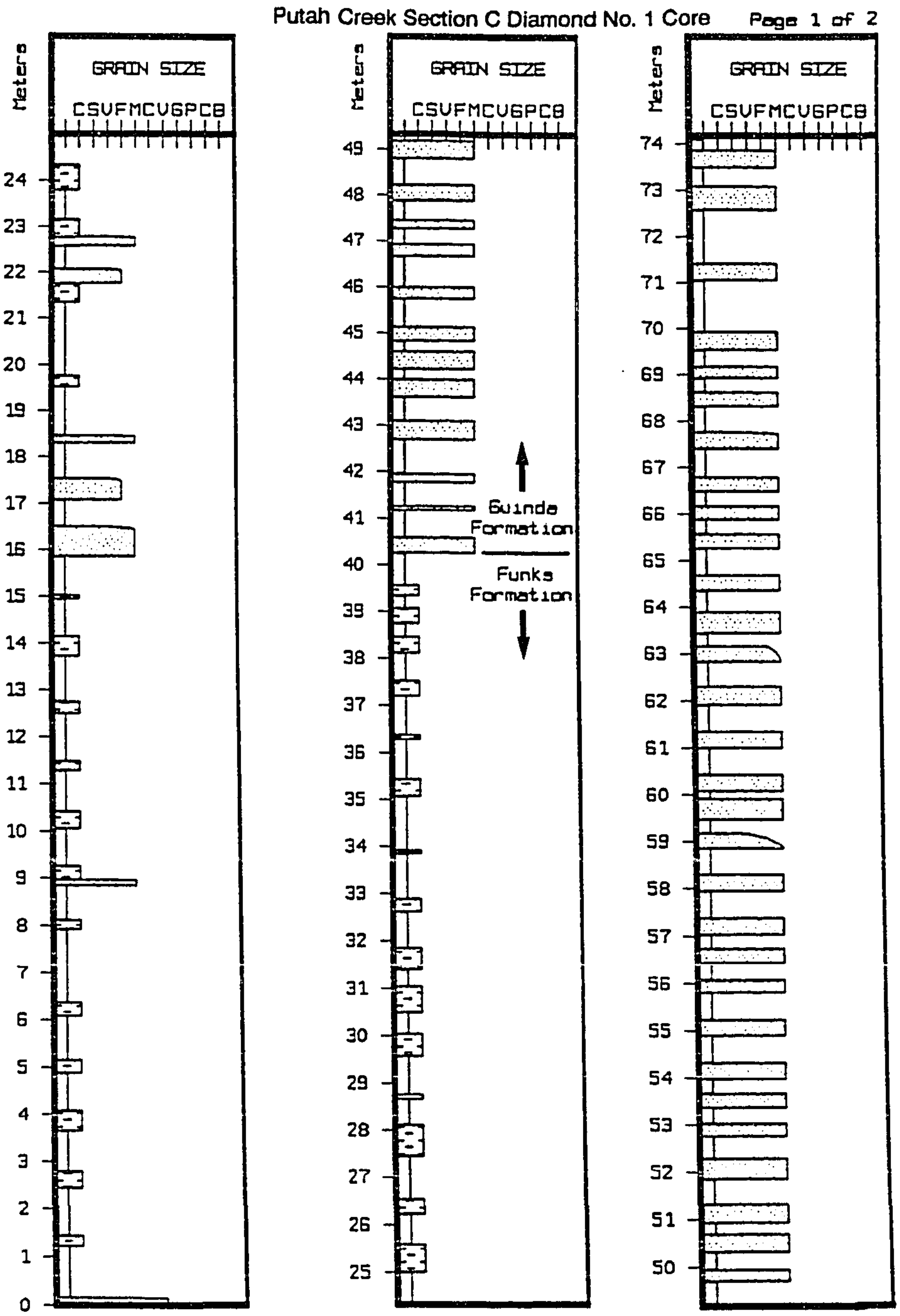


Figure 37. Measured core section of the Putah Creek Section C Diamond No. 1 core. See Appendix 1 for the explanation and Appendix 2 for the detailed core description.

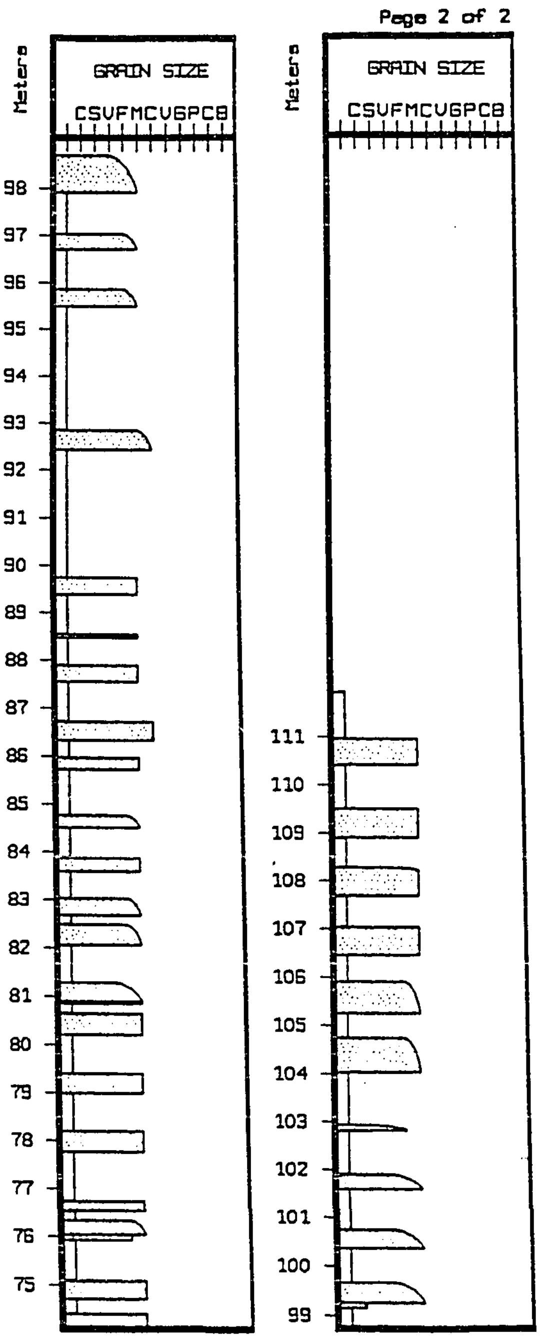


Figure 37 (cont'd).

The core is stored in a total of eight 28 by 102 cm (11 by 40 in) boxes, each of which contains individual sample bags filled with short, broken core fragments that were taken from intervals of between 0.6 and 1.5 m (two to five ft). The core pieces range from 2 to 3 cm (0.75 to 1.25 in) in diameter, and between 2.5 to 15 cm (one to six in) in length. Unfortunately, there are no markings on any of the core pieces that indicate their original orientation in the hole, which end is stratigraphically up or down, or its relationship to other pieces of core in the same bag.

As reported by Shell, a total of 121 m (396 ft) of core originally was recovered from this corehole, from a depth of between 18 to 139 m (60 to 456 ft) below the well's datum (which is assumed to be near ground level). Unfortunately, a large percentage of the original shale and siltstone and a significant portion of sandstone are no longer present, leaving only 38 m (125 ft), or 32 percent, of the original core available for study.

This corehole lies approximately 450 m (1500 ft) south and 300 m (100 ft) east of the outcrop section that was measured near Putah Creek for this report. The location of the corehole is shown on the geologic map of the Putah Creek measured outcrop section (fig. 26). The purpose of examining this core was to gauge the degree of lithologic variability between two closely spaced sections, and to investigate the extent that weathering has had on masking lithologic and sedimentologic details of surface exposures.

Description. The basal 40 m (131 ft) of recovered core, consists almost exclusively of shale, with some thin interbeds of massive, planar- and convolute-laminated sandstone. Much of this sequence is organically rich and well bedded. The thickness of this shale interval suggests that it is part of the Funks Formation.

Approximately 40 m (131 ft) of the above the base of the section, the lowest major Guinda sandstone is encountered. Practically no shale or siltstone remains through the next 72 m (236 ft) of section, and what does remain consists primarily of rubble; nevertheless, some information can be deduced from the rock.

The Guinda Formation interval generally consists of medium-grained, massive- to planar-bedded sandstone, with subangular to subrounded grains. Water that was sprayed onto the core to accent the bedding was readily absorbed into the rock, indicating high porosity. Because of the excellent preservation of the cored rock, fine stratigraphic details may be seen throughout the section that are rarely visible in outcrop. Figure 38 is a typical interval in the recovered core that reveals thin carbonaceous partings that accent the mostly planar bedding. A small fault, probably syndepositional, cuts

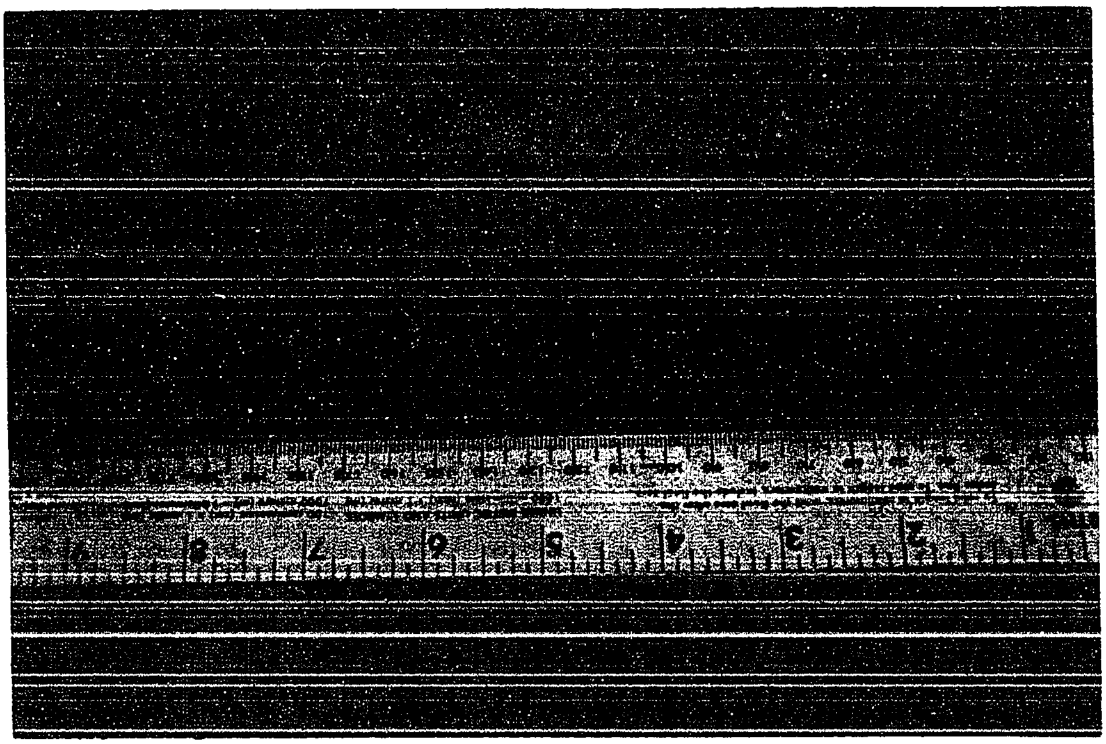


Figure 38. Thin planar beds typical of Bouma T_b beds from the Putah Creek Section C Diamond No. 1 core. Note the small syndepositional fault in the third section from the left. Top is believed to be toward the left. Photo taken from part of the 34- to 35-m (120- to 130-ft) recovered interval.

across a section of the core. Figure 39 is a section of core that exhibits some climbing ripple laminations that overlie a set of small cross beds.

Interpretation. Even without the fine-grained portion of the core to help in a stratigraphic reconstruction, subtle differences in grain size can be used to break out major stratigraphic intervals. Figure 40 depicts the core in a compressed format; for better clarity, all missing sections of core have been removed. Nine individual channel sequences of Facies B sandstone can be delineated from the recovered core based on delineating fining-upward packages, although this is somewhat speculative because of the missing sections of rock. Due to the proximity of the core hole to the Putah Creek measured section, a middle-fan environment is inferred. Thick intervals, which have been removed, probably contained finer-grained interchannel deposits.

If the fine-grained component is visually removed from the measured outcrop section, the inferred channel thicknesses are similar to those from the core. One major difference between the outcrop section and the core is that no conglomerate was recovered from the cored interval.

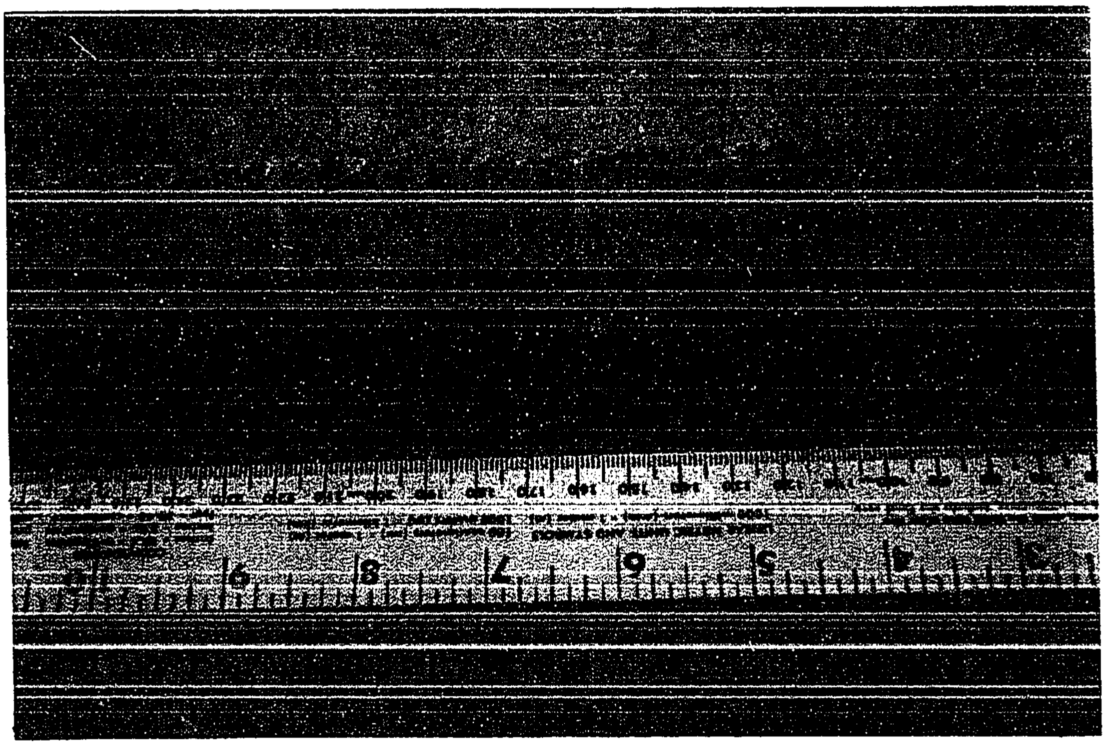


Figure 39. Climbing ripple laminations and cross bedding (located above the 6.5-inch mark on the scale) from the Putah Creek Section C Diamond No. 1 core. Top is towards the left. Photo taken from part of the 128- to 129-m (421- to 425-ft) recovered interval.

Putah Creek Section C Diamond No. 1 Core

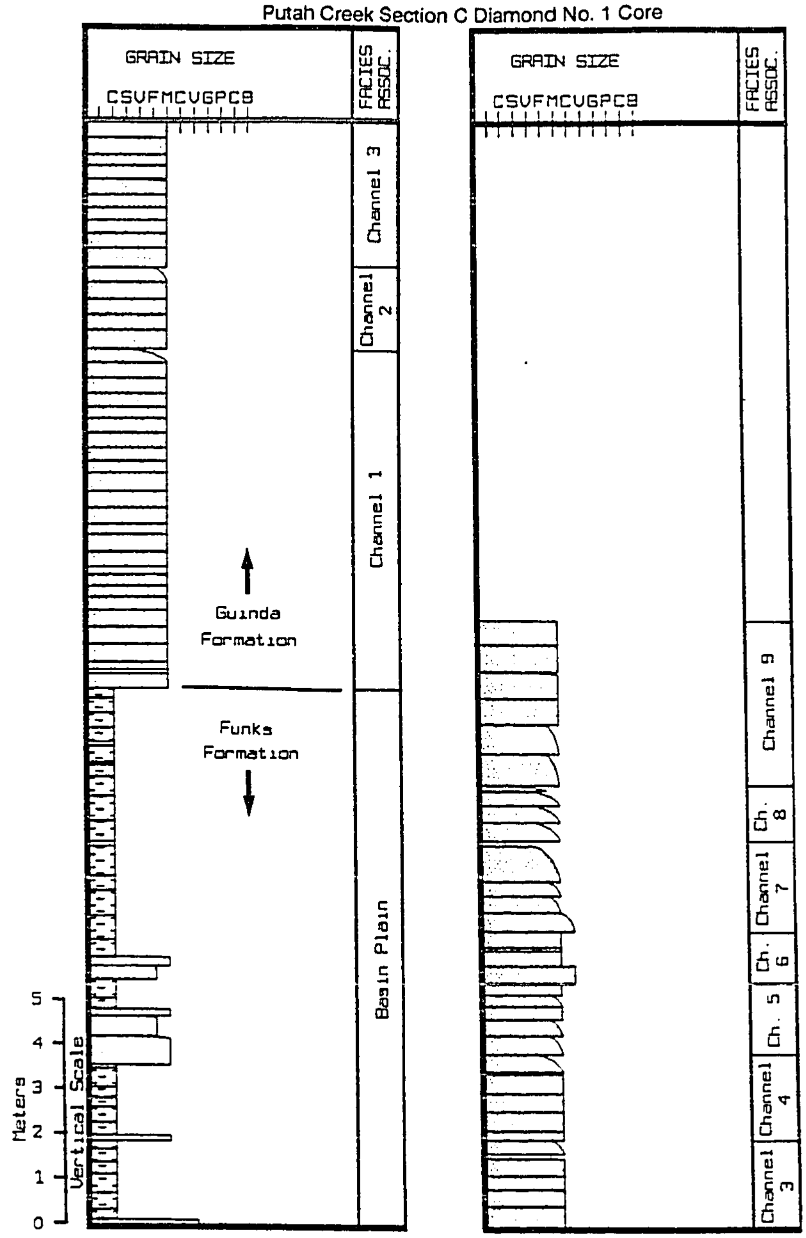


Figure 40. Interpreted schematic view of the Putah Creek Section C Diamond No. 1 core. All missing sections from the core have been removed for this view to simplify the process of making some generalities about the depositional environments. See Appendix 1 for the explanation and Appendix 2 for the detailed core description.

PALEOCURRENTS

Paleocurrent readings were gathered from the Guinda Formation at all of the measured sections except for the Mix Canyon section, where no reliable paleocurrent indicators were found. The numbers of beds and measurements made for each bed are listed in Table 2. Paleocurrents were determined from flute casts and scour marks.

In general, sandstone beds associated with outer-fan depositional lobe deposits contain the most abundant and reliable paleocurrent indicators, so most of the measurements are from the lower half of the Guinda Formation. All other paleocurrent indicators are associated with channel deposits. The reason for the majority of the paleocurrent indicators appearing in outer-fan lobe deposits rather than channel deposits probably is that more interbedded sandstones and shales occur here than in the channel deposits; channel sequences commonly are amalgamated. Erosion of shale exposes superjacent sandstone beds for better observation of flute casts.

The raw data and the corrections for bed-tilt are shown in Table 3. No corrections for fold plunge were required because of the simple homoclinal nature of the rocks. Data required for the generation of circular histograms (rose diagrams) and a statistical summary of the

Table 2

Paleocurrent Measurements

LOCATION	NUMBER OF BEDS	NUMBER OF MEASUREMENTS
Black Butte Reservoir	13	48
South Fork of Willow Creek	8	24
Salt Creek	5	12
Putah Creek, Bray Canyon	6	16
Ulatis Creek, Mix Canyon	0	0
Alamo Creek, Gates Canyon	8	25
TOTALS:	40	125

Table 3

Paleocurrent Data

LOCATION	BED STRIKE	BED DIP	RAW LINEATION TREND	CORRECTED LINEATION AZIMUTH
Black Butte	357	26	12	194
Black Butte	257	26	14	196
Black Butte	357	26	17	199
Black Butte	357	26	22	204
Black Butte	357	25	6	187
Black Butte	357	25	6	187
Black Butte	357	25	8	189
Black Butte	357	25	12	194
Black Butte	354	23	3	184
Black Butte	356	24	28	211
Black Butte	356	24	30	213
Black Butte	356	24	32	215
Black Butte	357	26	14	196
Black Butte	357	26	4	185
Black Butte	357	26	5	186
Black Butte	357	26	18	200
Black Butte	358	28	177	177
Black Butte	358	28	178	178
Black Butte	358	28	179	179
Black Butte	358	28	150	147
Black Butte	358	28	151	148
Black Butte	355	29	8	190
Black Butte	355	29	2	183
Black Butte	355	29	2	183
Black Butte	356	29	14	197
Black Butte	356	29	8	190
Black Butte	356	29	12	194
Black Butte	356	29	12	194
Black Butte	354	29	6	188
Black Butte	354	29	15	198
Black Butte	354	29	10	192
Black Butte	354	29	10	192
Black Butte	354	29	11	193
Black Butte	354	29	10	192
Black Butte	353	28	2	183
Black Butte	353	28	5	187
Black Butte	353	28	12	194
Black Butte	353	28	13	195
Black Butte	353	28	9	191
Black Butte	353	28	10	192
Black Butte	353	28	5	187
Black Butte	350	25	277	178
Black Butte	350	24	175	176
Black Butte	350	24	174	174
Black Butte	350	24	175	176
Black Butte	350	24	172	172
Black Butte	350	24	170	170
Black Butte	349	25	3	184
Willow Creek	353	67	92	267
Willow Creek	353	67	98	269

Table 3 (cont'd)

Page 2 of 3

LOCATION	BED STRIKE	BED DIP	RAW LINEATION TREND	CORRECTED LINEATION AZIMUTH
Willow Creek	353	67	97	269
Willow Creek	353	69	88	265
Willow Creek	353	69	54	251
Willow Creek	353	69	90	266
Willow Creek	355	66	75	261
Willow Creek	355	66	80	263
Willow Creek	355	66	89	267
Willow Creek	355	66	96	270
Willow Creek	355	64	102	272
Willow Creek	353	58	16	211
Willow Creek	353	58	25	223
Willow Creek	354	57	66	254
Willow Creek	354	57	68	256
Willow Creek	354	57	75	260
Willow Creek	355	57	82	263
Willow Creek	355	57	84	264
Willow Creek	355	57	77	261
Willow Creek	355	57	74	259
Willow Creek	353	56	104	276
Willow Creek	353	56	110	279
Willow Creek	353	56	105	276
Willow Creek	353	56	113	281
Salt Creek	355	32	48	233
Salt Creek	355	32	52	236
Salt Creek	355	32	55	239
Salt Creek	354	33	36	221
Salt Creek	354	33	36	221
Salt Creek	355	31	45	229
Salt Creek	355	27	89	269
Salt Creek	355	27	80	261
Salt Creek	355	27	82	262
Salt Creek	356	21	66	247
Salt Creek	356	21	72	253
Salt Creek	356	21	74	255
Putah Creek	356	59	8	202
Putah Creek	352	58	176	180
Putah Creek	352	58	165	159
Putah Creek	352	58	169	166
Putah Creek	352	54	4	194
Putah Creek	352	54	8	200
Putah Creek	352	57	177	181
Putah Creek	348	54	18	212
Putah Creek	348	54	14	208
Putah Creek	348	54	14	208
Putah Creek	348	54	14	208
Putah Creek	348	54	6	197
Putah Creek	350	53	172	173
Putah Creek	350	53	178	183
Putah Creek	350	53	9	200
Putah Creek	350	53	12	204
Gates Canyon	346	54	96	268
Gates Canyon	346	54	97	269
Gates Canyon	346	54	95	267
Gates Canyon	344	54	77	257

Table 3 (cont'd)

LOCATION	BED STRIKE	BED DIP	RAW LINEATION TREND	CORRECTED LINEATION AZIMUTH
Gates Canyon	344	54	79	258
Gates Canyon	344	54	79	258
Gates Canyon	345	49	52	239
Gates Canyon	345	49	66	249
Gates Canyon	345	49	68	250
Gates Canyon	345	49	46	235
Gates Canyon	342	45	80	257
Gates Canyon	342	45	89	265
Gates Canyon	342	45	85	262
Gates Canyon	343	44	94	268
Gates Canyon	343	44	96	270
Gates Canyon	343	44	98	272
Gates Canyon	343	44	99	272
Gates Canyon	343	44	102	275
Gates Canyon	341	41	88	264
Gates Canyon	341	41	89	265
Gates Canyon	341	41	18	206
Gates Canyon	345	41	21	209
Gates Canyon	341	41	47	232
Gates Canyon	341	41	47	232
Gates Canyon	341	41	52	236

paleocurrent data are shown in Table 4. Circular histograms generated from these data are shown in Figure 41.

These data indicate a general southwestward flow direction; however, two distinct maxima exist: (1) a south-southwest flow direction, and (2), a west-southwest flow direction. Paleocurrent measurements taken from the Guinda Formation at Black Butte Reservoir and Putah Creek show a strong southward flow direction, whereas the South Fork of Willow Creek, Salt Creek, and Alamo Creek in Gates Canyon have current directions that are more westward. Thus, regional paleocurrent data from the Guinda Formation appear to reflect a complex fan environment.

Several possibilities exist that would account for two flow directions: (1) there were localized differences in fan morphology and/or topographic relief, (2) there were local or regional topographic differences in the basement rock that caused sediment-gravity flows to pass around highs or into lows, (3) there were local differences in the basin slope of the Upper Cretaceous forearc basin, (4) there were differences in bottom contour or slope-parallel currents, and/or (5) the Guinda fan system is composed of several distinct fans. The absence of any eastward or northward paleocurrents suggests that sediment was not actively being shed from the west off of any structural highs, for example in the coeval Franciscan subduction

Table 4

Statistical Summaries of Paleocurrent Data
for Circular Histograms

Guinda Formation Composite (all data)

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	2	2
151-180	13	10
181-210	47	38
211-240	17	14
241-270	38	30
271-300	8	6
301-330	0	0
331-360	0	0
n=	125	
Mean	221	

Vector Magnitude (%) = 81
Rayleigh Significance= 5.23E-36
Circular Standard Dev= 35
Circular Variance = 1212

Black Butte Reservoir Measured Section

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	2	4
151-180	9	19
181-210	34	71
211-240	3	6
241-270	0	0
271-300	0	0
301-330	0	0
331-360	0	0
n=	48	
Mean	188	

Vector Magnitude (%) = 98
Rayleigh Significance= 1.46E-20
Circular Standard Dev= 9
Circular Variance = 88

South Fork Willow Creek Measured Section

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	0	0
151-180	0	0
181-210	0	0
211-240	2	8
241-270	17	71
271-300	5	21
301-330	0	0
331-360	0	0
n=	24	
Mean	262	

Vector Magnitude (%) = 97
Rayleigh Significance= 1.96E-10
Circular Standard Dev= 13
Circular Variance = 157

Salt Creek, Capay Hills Measured Section

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	0	0
151-180	0	0
181-210	0	0
211-240	6	50
241-270	6	50
271-300	0	0
301-330	0	0
331-360	0	0
n=	12	
Mean	244	

Vector Magnitude (%) = 96
Rayleigh Significance= 1.46E-05
Circular Standard Dev= 13
Circular Variance = 169

Table 4 (cont'd)

Putah Creek, North Side Measured Section

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	0	0
151-180	4	25
181-210	11	69
211-240	1	6
241-270	0	0
271-300	0	0
301-330	0	0
331-360	0	0
n=	16	
Mean	192	

Vector Magnitude (%) =	96
Rayleigh Significance=	3.68E-07
Circular Standard Dev=	13
Circular Variance =	175

Alamo Creek, Gates Canyon Measured Section

ROSE DIAGRAM INTERVAL	#	%
>0- 30	0	0
31- 60	0	0
61- 90	0	0
91-120	0	0
121-150	0	0
151-180	0	0
181-210	2	8
211-240	5	20
241-270	15	60
271-300	3	12
301-330	0	0
331-360	0	0
n=	25	
Mean	254	

Vector Magnitude (%) =	95
Rayleigh Significance=	1.72E-10
Circular Standard Dev=	16
Circular Variance =	268

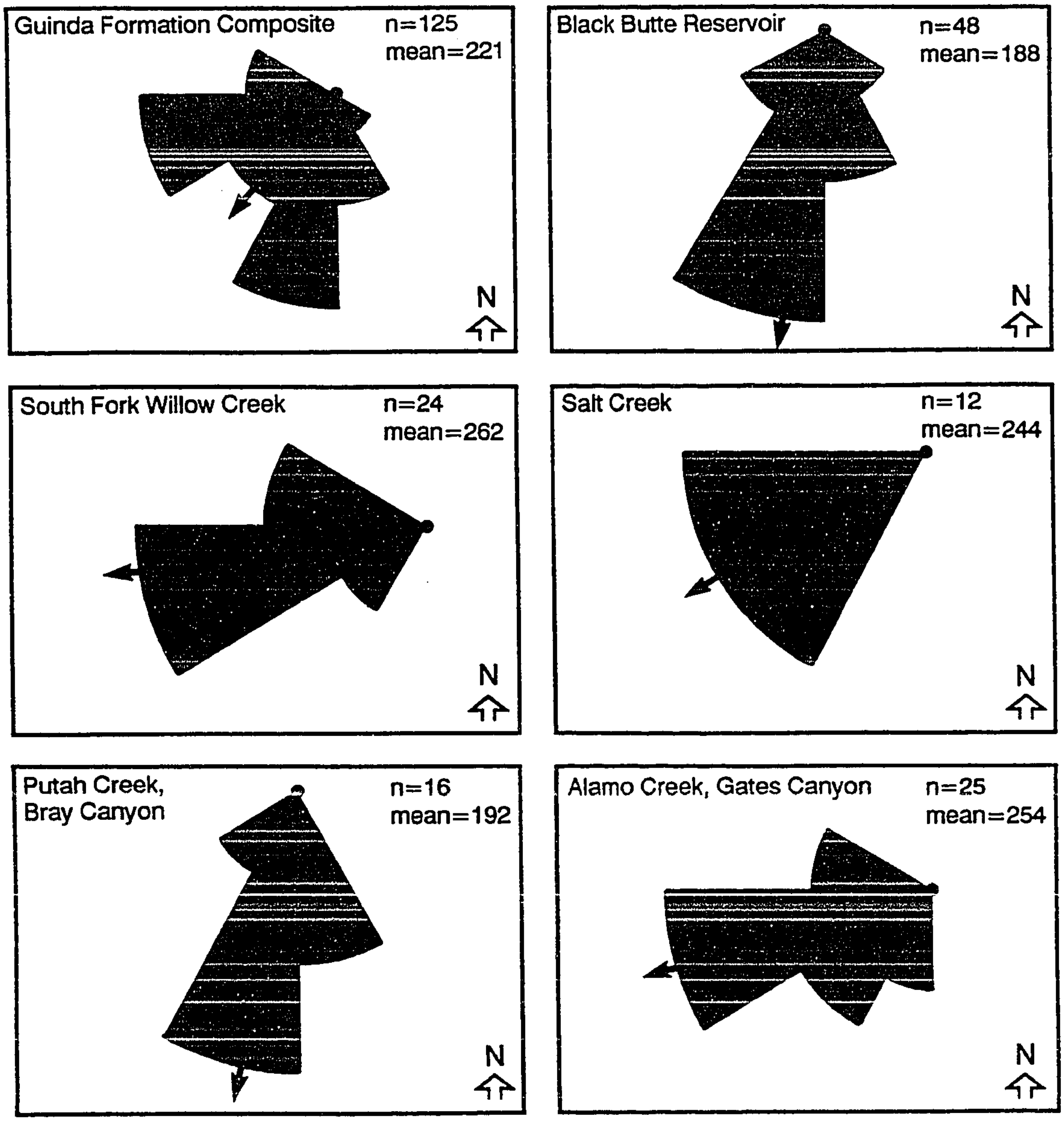


Figure 41. Circular histograms of paleocurrent data for each of the measured sections and a composite for all data. Arrows indicate vector mean direction.

complex, or from the south.

The paleocurrent data generated for this report are compatible with the paleogeographic reconstructions of Ingersoll (1976, 1977, 1978a, 1978b, 1979, 1981, 1982, 1983), and paleocurrent data collected by others (Chuber, 1962; Rozelle, 1968; Ojakangas, 1964, 1968; Swe, 1968; Johnson and Hampton, 1969; Lowe, 1972; Ingersoll, 1976) from adjacent units of the Great Valley Group are in general agreement with the results from this study. Ojakangas (1964, 1968) noted the predominance of south-directed paleocurrents within the Sacramento basin. Ojakangas (1964, 1968) gathered 14 paleocurrent measurements from the Guinda Formation in the Capay Hills, which showed paleocurrents flowing towards the southwest (230°). He reported one additional paleocurrent measurement from the Guinda Formation along Putah Creek that reflects a flow direction towards the south-southeast (140°).

PETROGRAPHY

Thin Sections

Fifteen sandstone samples were studied so that inferences concerning source terranes could be made. Petrographic sample locations are shown on the geologic maps in the chapter on lithostratigraphy (figs. 7, 15, 20, 26, 30, 34). The thin-section samples, their general location, and the approximate stratigraphic position from which they were retrieved are listed in Table 5.

Seven petrographic components were defined for each thin section (table 6). These data were then used to calculate relevant petrographic parameters for these rocks (table 7). The results of this work are listed on Table 8, and the data that were used to define the various petrographic ternary plots presented later in this chapter are given in Table 9.

Sandstones of the Guinda Formation generally range from fine to medium grained (0.12-0.50 mm). Most samples are moderately to poorly sorted (σ=0.75-1.5ϕ), resulting in a typical range of grain size from medium silt to coarse-grained sand. Grains typically are subangular to subrounded. Many of the sandstones are matrix-rich, averaging over 12%; most of the matrix appears to have resulted from compactional and diagenetic alteration.

Table 5

Locations and Stratigraphic Positions of Petrographic Samples

SAMPLE ID	MEASURED SECTION	SAMPLE LOCATION	STRATIGRAPHIC POSITION
89-DBS-01SS	Black Butte Reservoir	SE SE sec. 31, T.23N, R.4W	Lower Guinda Fm.
89-DBS-04SS	Black Butte Reservoir	NE SE sec. 31, T.23N, R.4W	Upper Guinda Fm.
90-DBS-22SS	South Fork Willow Creek	SW NE sec. 9, T.19N, R.4W	Lower Guinda Fm.
90-DBS-26SS	South Fork Willow Creek	NE SE sec. 9, T.19N, R.4W	Upper Guinda Fm.
90-DBS-28SS	Salt Creek, Capay Hills	NW SE sec. 33, T.13N, R.3W	Lower Guinda Fm.
90-DBS-29SS	Salt Creek, Capay Hills	NW SE sec. 33, T.13N, R.3W	Mid-Lower Guinda Fm.
90-DBS-38SS	Salt Creek, Capay Hills	NW SE sec. 33, T.13N, R.3W	Middle Guinda Fm.
90-DBS-30SS	Salt Creek, Capay Hills	SW SW sec. 34, T.13N, R.3W	Mid-Upper Guinda Fm.
90-DBS-31SS	Salt Creek, Capay Hills	SW SW sec. 34, T.13N, R.3W	Upper Guinda Fm.
90-DBS-14SS	Bray Canyon, Putah Creek	SE SE sec. 21, T. 8N, R.2W	Lower Guinda Fm.
90-DBS-12SS	Bray Canyon, Putah Creek	SW SW sec. 22, T. 8N, R.2W	Upper Guinda Fm.
90-DBS-04SS	Ulatis Creek, Mix Canyon	NW SW sec. 34, T. 7N, R.2W	Lower Guinda Fm.
90-DBS-06SS	Ulatis Creek, Mix Canyon	NW SW sec. 34, T. 7N, R.2W	Upper Guinda Fm.
90-DBS-33SS	Alamo Creek, Gates Canyon	SW SE sec. 3, T. 6N, R.2W	Lower Guinda Fm.
90-DBS-32SS	Alamo Creek, Gates Canyon	SE SE sec. 3, T. 6N, R.2W	Upper Guinda Fm.

Table 6

Grain Catagories and Petrographic Components

Q = Qm + Qp	where Q = total quartzose grains Qm = monocrystalline quartz grains Qp = polycrystalline quartz grains
F = P + K	where F = total feldspar grains P = plagioclase feldspar grains K = potassium feldspar grains
Lt = L + Qp	where Lt = total aphanitic lithic grains L = total unstable aphanitic lithic grains
L = Lv + Lvm + Ls + lsm	where Lv = aphanitic volcanic lithic grains Lvm = aphanitic metavolcanic lithic grains Ls = aphanitic sedimentary lithic grains Lsm = aphanitic metasedimentary lithic grains
Lm = Lvm + Lsm	where Lm = aphanitic metamorphic lithic grains
Miscellaneous (M and Mc)	where M = monocrystalline phylosilicate grains (mica) Mc = miscellaneous and unidentified framework grains
Rock Fragments (R)	where R = all rock fragments other than Q and F, (chert included as part of Q)

Table 7

Petrographic Modal Data

SAMPLE	GENERAL LOCATION	FRAMEWORK GRAINS (QFL%)											MISC.		CE-MENT (%)	MA-TRIX (%)	PORE (%)
		QUARTZ			FELDSPAR			LITHIC FRAGMENTS									
		Qm (%)	Qp (%)	QFL %Q	P (%)	K (%)	QFL %F	Lv (%)	Lvm (%)	Ls (%)	Lsm (%)	QFL %L	M (%)	Mc (%)			
89-DBS-01SS	BB-l Kg	30.0	7.3	37.3	24.3	19.7	44.0	8.0	9.4	1.0	0.3	18.7	5.0	1.3	10.2	13.2	11.5
89-DBS-04SS	BB-u Kg	25.0	6.0	31.0	34.7	6.0	40.7	17.7	10.3	0.3	0.0	28.3	12.0	3.3	5.8	28.2	9.2
90-DBS-22SS	WC-l Kg	29.3	9.0	38.3	21.0	16.0	37.0	10.7	10.6	2.7	0.7	24.7	8.0	5.3	15.1	6.5	13.9
90-DBS-26SS	WC-u Kg	29.0	5.0	34.0	32.7	9.0	41.7	16.0	6.7	1.3	0.3	24.3	9.0	1.3	4.5	15.4	14.8
90-DBS-28SS	SC-l Kg	34.3	5.7	40.0	34.0	10.0	44.0	10.1	4.3	1.3	0.3	16.0	4.7	4.7	3.9	6.4	13.9
90-DBS-29SS	SC-lm Kg	33.0	5.0	38.0	29.3	9.3	38.7	18.6	4.0	0.7	0.0	23.3	9.3	3.0	4.0	11.3	13.8
90-DBS-38SS	SC-m Kg	32.0	9.0	41.0	30.7	13.0	43.7	11.0	3.3	1.0	0.0	15.3	5.0	7.0	10.2	7.7	17.1
90-DBS-30SS	SC-um Kg	30.7	12.0	42.7	26.3	13.0	39.3	11.4	6.3	0.3	0.0	18.0	7.0	5.3	7.5	11.6	12.4
90-DBS-31SS	SC-u Kg	34.0	7.3	41.3	27.0	12.0	39.0	12.3	5.4	1.3	0.7	19.7	10.0	2.0	8.9	15.2	10.3
90-DBS-14SS	PC-l Kg	20.7	8.7	29.4	31.3	11.7	43.0	22.7	3.9	1.0	0.0	27.6	12.0	1.0	14.5	11.8	9.6
90-DBS-12SS	PC-u Kg	26.3	9.7	36.0	34.0	9.3	43.3	16.7	3.3	0.7	0.0	20.7	6.0	2.0	3.6	10.8	9.7
90-DBS-04SS	MC-l Kg	36.7	8.3	45.0	27.0	13.0	40.0	9.3	4.0	1.0	0.7	15.0	14.0	1.0	21.5	7.2	10.5
90-DBS-06SS	MC-u Kg	26.0	9.7	35.7	31.3	14.0	45.3	16.6	2.7	0.0	0.7	20.0	13.0	4.0	7.2	12.0	11.5
90-DBS-33SS	GC-l Kg	40.7	6.3	47.0	25.0	15.0	40.0	6.0	5.3	1.0	0.7	13.0	7.0	6.0	11.6	11.2	5.2
90-DBS-32SS	GC-u Kg	34.3	7.3	41.6	30.7	10.0	40.7	13.0	3.0	0.7	1.0	17.7	6.0	6.7	6.0	12.7	8.6
MINIMUM VALUE		20.7	5.0	29.4	21.0	6.0	37.0	6.0	2.7	0.0	0.0	13.0	4.7	1.0	3.6	6.4	5.2
MAXIMUM VALUE		40.7	12.0	47.0	34.7	19.7	45.3	22.7	10.7	2.7	1.0	28.3	14.0	7.0	21.5	28.2	17.1
SAMPLE MEAN		30.8	7.6	38.6	29.3	12.1	41.3	13.3	5.5	1.0	0.4	20.1	8.5	3.6	9.0	12.1	11.5
STAND. DEVIATION (±)		5.1	2.0	4.9	4.0	3.4	2.4	4.6	2.7	0.6	0.4	4.7	3.1	2.1	5.1	5.3	3.0

Abbreviations for General Location: BB=Black Butte Reservoir, WC=Willow Creek, SC=Salt Creek, PC=Putah Creek, MC=Mix Canyon, GC=Gates Canyon, l Kg=lower Guinda Fm., u Kg=upper Guinda Fm., m Kg=middle Guinda Fm., lm Kg=lower-middle Guinda Fm., um Kg=upper-middle Guinda Fm.

Table 8

Calculated Values Used to Define the Seven Key Petrographic Parameters

SAMPLE	GENERAL LOCATION	P/F (%)	Lv/L (%)	FRAME-WORK %M	Qp/Q (%)	QFL %Q	QFL %F	QFL %L
89-DBS-01SS	BB-l Kg	55.2	42.8	5.0	19.6	37.3	44.0	18.7
89-DBS-04SS	BB-u Kg	85.3	62.5	12.0	19.4	31.0	40.7	28.3
90-DBS-22SS	WC-l Kg	56.8	43.3	8.0	23.5	38.3	37.0	24.7
90-DBS-26SS	WC-u Kg	78.4	65.8	9.0	14.7	34.0	41.7	24.3
90-DBS-28SS	SC-l Kg	77.3	62.5	4.7	14.2	40.0	44.0	16.0
90-DBS-29SS	SC-lm Kg	75.7	80.3	9.3	13.2	38.0	38.7	23.3
90-DBS-38SS	SC-m Kg	70.3	71.9	5.0	22.0	41.0	43.7	15.3
90-DBS-30SS	SC-um Kg	66.9	62.8	7.0	28.1	42.7	39.3	18.0
90-DBS-31SS	SC-u Kg	69.2	62.4	10.0	17.7	41.3	39.0	19.7
90-DBS-14SS	PC-l Kg	72.8	81.9	12.0	29.7	29.4	43.0	27.6
90-DBS-12SS	PC-u Kg	78.5	80.7	6.0	26.9	36.0	43.3	20.7
90-DBS-04SS	MC-l Kg	67.5	62.0	14.0	18.4	45.0	40.0	15.0
90-DBS-06SS	MC-u Kg	69.1	87.9	13.0	27.2	35.7	45.3	20.0
90-DBS-33SS	GC-l Kg	62.5	46.1	7.0	13.4	47.0	40.0	13.0
90-DBS-32SS	GC-u Kg	75.4	73.4	6.0	17.5	41.6	40.7	17.7
MINIMUM VALUE		55.2	42.8	4.7	13.2	29.4	37.0	13.0
MAXIMUM VALUE		85.3	87.9	14.0	29.7	47.0	45.3	28.3
SAMPLE MEAN		70.7	65.8	8.5	20.4	38.6	41.3	20.1
STAND. DEVIATION (±)		8.3	14.0	3.1	5.6	4.9	2.4	4.7

Abbreviations for General Location: BB=Black Butte Reservoir, WC=Willow Creek, SC=Salt Creek, PC=Putah Creek, MC=Mix Canyon, GC=Gates Canyon, l Kg=lower Guinda Fm., u Kg=upper Guinda Fm., m Kg=middle Guinda Fm., lm Kg=lower-middle Guinda Fm., um Kg=upper-middle Guinda Fm.

Table 9

Calculated Values Used to Define the Five Petrographic Ternary Diagrams

SAMPLE	GENERAL LOCATION	QFL			QmFLt			QmPK			LmLvLs			QpLvmLsm		
		%Q	%F	%L	%Qm	%F	%Lt	%Qm	%P	%K	%Lm	%Lv	%Ls	%Qp	%Lvm	%Lsm
89-DBS-01SS	BB-l Kg	37.3	44.0	18.7	30.0	44.0	26.0	40.2	32.9	26.9	51.6	43.0	5.4	43.2	55.0	1.8
89-DBS-04SS	BB-u Kg	31.0	40.7	28.3	25.0	40.7	34.3	38.1	52.8	9.1	36.4	62.5	1.1	36.8	63.2	0.0
90-DBS-22SS	WC-l Kg	38.3	37.0	24.7	29.3	37.0	33.7	44.2	31.7	24.1	45.9	43.2	10.9	44.1	52.5	3.4
90-DBS-26SS	WC-u Kg	34.0	41.7	24.3	29.0	41.7	29.3	41.0	46.3	12.7	28.8	65.8	5.4	41.7	55.8	2.5
90-DBS-28SS	SC-l Kg	40.0	44.0	16.0	34.3	44.0	21.7	43.8	43.4	12.8	28.9	62.9	8.2	55.3	41.8	2.9
90-DBS-29SS	SC-lm Kg	38.0	38.7	23.3	33.0	38.7	28.3	46.1	40.9	13.0	17.1	79.9	3.0	55.6	44.4	0.0
90-DBS-38SS	SC-m Kg	41.0	43.7	15.3	32.0	43.7	24.3	42.2	40.6	17.2	21.6	71.9	6.5	73.2	26.8	0.0
90-DBS-30SS	SC-um Kg	42.7	39.3	18.0	30.7	39.3	30.0	43.8	37.6	18.6	35.2	63.1	1.7	65.6	34.4	0.0
90-DBS-31SS	SC-u Kg	41.3	39.0	19.7	34.0	39.0	27.0	46.6	37.0	16.4	30.6	62.8	6.6	54.9	39.8	5.3
90-DBS-14SS	PC-l Kg	29.4	43.0	27.6	20.7	43.0	36.3	32.5	49.1	18.4	14.4	82.0	3.6	68.5	31.5	0.0
90-DBS-12SS	PC-u Kg	36.0	43.3	20.7	26.3	43.3	30.4	37.7	48.9	13.4	15.9	80.7	3.4	74.6	25.4	0.0
90-DBS-04SS	MC-l Kg	45.0	40.0	15.0	36.7	40.0	23.3	47.9	35.2	16.9	31.3	62.0	6.7	63.8	30.8	5.4
90-DBS-06SS	MC-u Kg	35.7	45.3	20.0	26.0	45.3	28.7	36.5	43.9	19.6	16.9	83.1	0.0	74.1	20.6	5.3
90-DBS-33SS	GC-l Kg	47.0	40.0	13.0	40.7	40.0	19.3	50.4	31.0	18.6	46.1	46.2	7.7	51.2	43.1	5.7
90-DBS-32SS	GC-u Kg	41.6	40.7	17.7	34.3	40.7	25.0	45.8	40.9	13.3	22.6	73.4	4.0	64.6	26.6	8.8
MINIMUM VALUE		29.4	37.0	13.0	20.7	37.0	19.3	32.5	31.0	9.1	14.4	43.0	0.0	36.8	20.6	0.0
MAXIMUM VALUE		47.0	45.3	28.3	40.7	45.3	36.4	50.4	52.8	26.9	51.6	73.1	10.9	74.6	63.2	8.8
SAMPLE MEAN		38.6	41.3	20.1	30.8	41.4	27.8	42.5	40.8	16.7	29.6	65.5	4.9	57.9	39.4	2.7
STAND. DEVIATION (±)		4.9	2.4	4.7	5.1	2.4	4.8	4.8	6.7	4.7	11.8	13.5	2.9	12.6	12.9	2.8

Abbreviations for General Location: BB=Black Butte Reservoir, WC=Willow Creek, SC=Salt Creek, PC=Putah Creek, MC=Mix Canyon, GC=Gates Canyon, l Kg=lower Guinda Fm., u Kg=upper Guinda Fm., m Kg=middle Guinda Fm., lm Kg=lower-middle Guinda Fm., um Kg=upper-middle Guinda Fm.

Grains generally are cemented by calcite. The sandstones typically contain a significant amount of visible pore space, averaging over 11% per sample, in the form of intergranular and leached-particle (secondary) porosity. The ratio of secondary porosity to intergranular porosity is about 2:1. Texturally, the Guinda Formation may be classified as immature to submature.

Removal of all metamorphic influences (Dickinson et al., 1969) was the most difficult problem encountered in doing the point counts in these samples was . Most commonly, the Guinda Formation exhibits albitization of plagioclase (which, for point counting, was recorded as plagioclase) and chloritization of biotite. Other diagenetic alterations include replacement of grains by calcite and crushing of lithic grains. Such diagenetic alterations were mentally removed during point counting.

The fabric of the Guinda Formation suggests that the sandstones have undergone a significant amount of mechanical and chemical compaction. Many of the grains are fractured and shattered into a "pseudo matrix" of mechanically unstable framework constituents, such as plagioclase, mica, and various volcanic and metamorphic lithic fragments. In matrix-rich samples, grain-to-grain contacts and compactional deformation features are abundant. In samples with abundant secondary porosity, compactional features and grain-to-grain contacts are common.

Of the framework grains, total quartz and feldspar are about equally proportioned, each composing about 40% of the rock, whereas total lithic fragments comprise about 20% of the rock. Accessory minerals compose less than 7% of the rock. Cements include calcite, pyrite, and various clay minerals.

The major pore-filling constituent within the sandstone is clay. X-ray diffraction data by Neasham and Tompkins (1982) from sandstone samples taken from Guinda Formation in the Capay Hills indicate that of the clay minerals, illite constitutes about 40% of the total, smectite about 24%, chlorite about 22%, and kaolinite less than 1%. The remaining 13% consists of undifferentiated non-expandable clays. With the exception of the clay matrix, only trace amounts of quartz overgrowths and opaque minerals (chiefly pyrite) occur.

Petrographic modal data from the Guinda Formation are summarized on ternary plots (figs. 42 through 47) and on a plot of selected ratios of framework constituents (fig. 48). The samples generally cluster on the ternary plots, showing a compositional uniformity in the sandstones of the Guinda Formation.

Sandstones of the Guinda Formation are classified as lithic arkoses in the classification scheme of Folk et al. (1970), as shown on a QFR ternary plot (fig. 42). The QFL

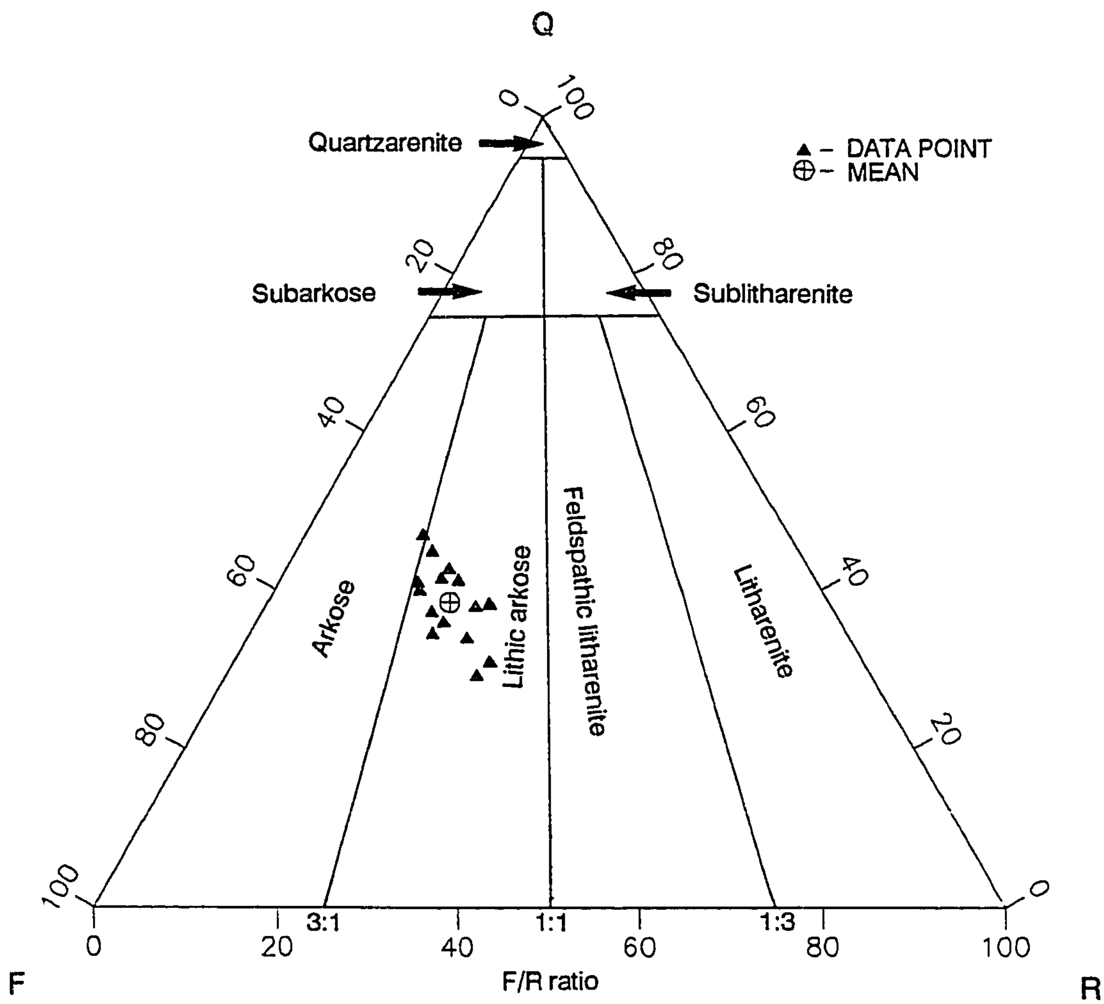


Figure 42. QFR ternary plot from sandstone samples of the Guinda Formation (classification scheme from Folk, 1980).

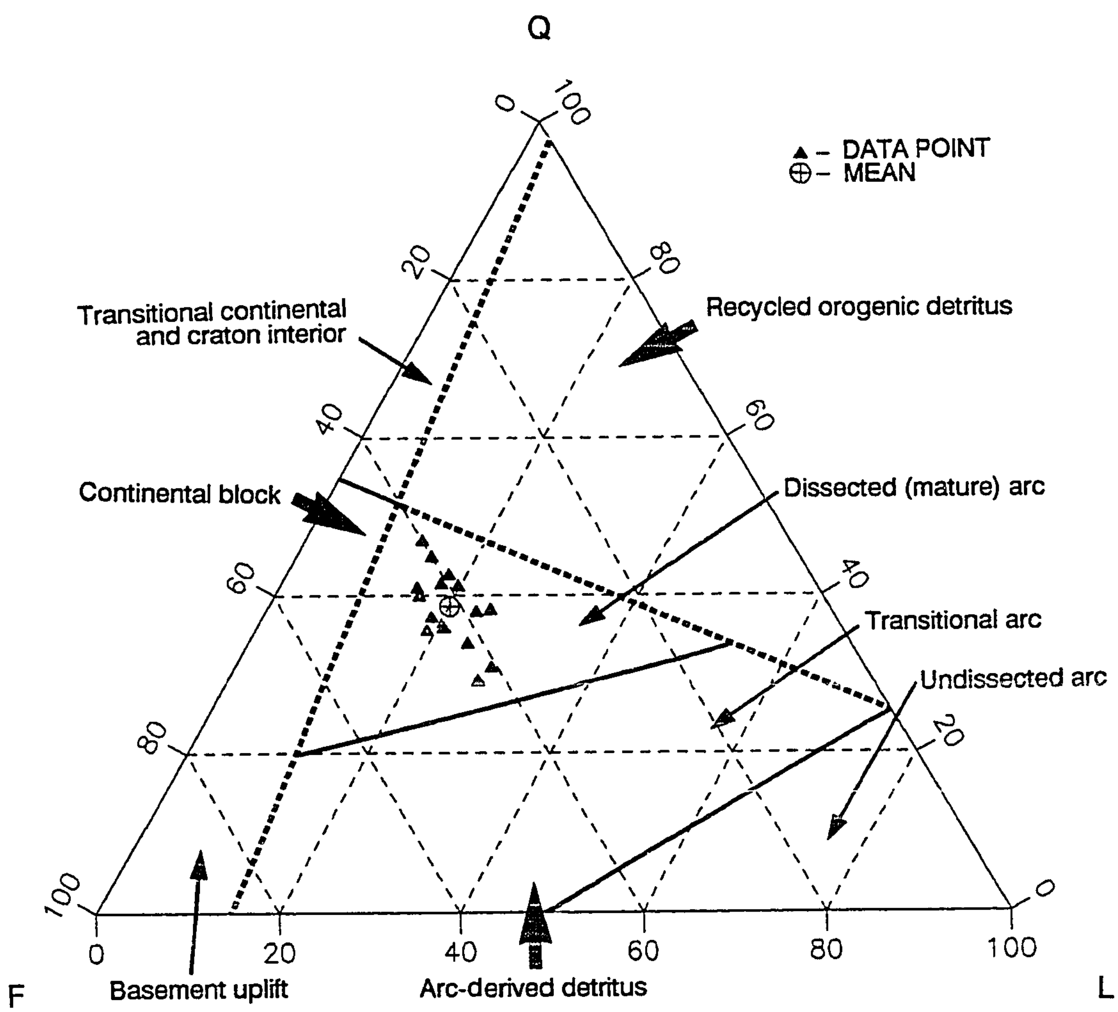


Figure 43. QFL ternary plot from sandstone samples of the Guinda Formation (provenance zones from Dickinson et al., 1983).

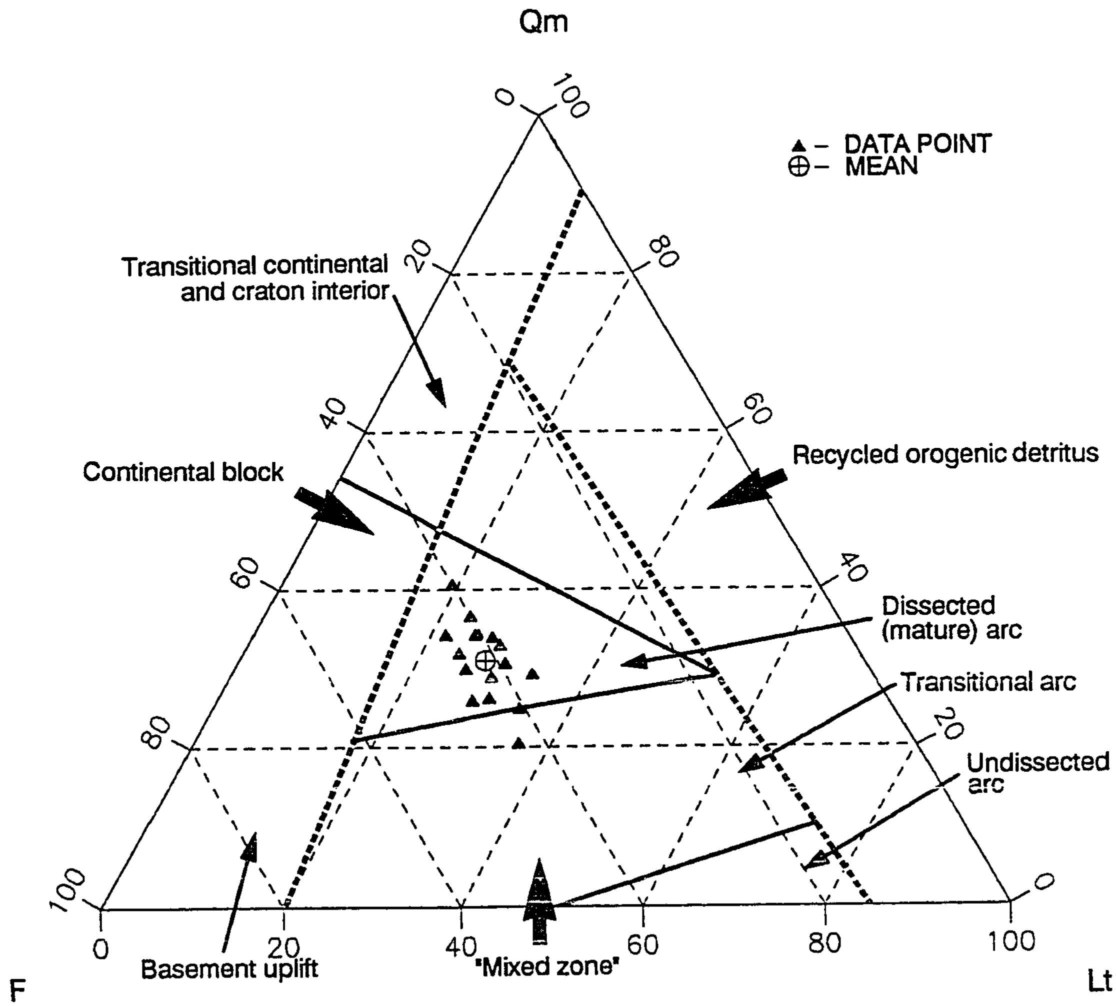


Figure 44. QmFLt ternary plot from sandstone samples of the Guinda Formation (provenance zones from Dickinson et al., 1983).

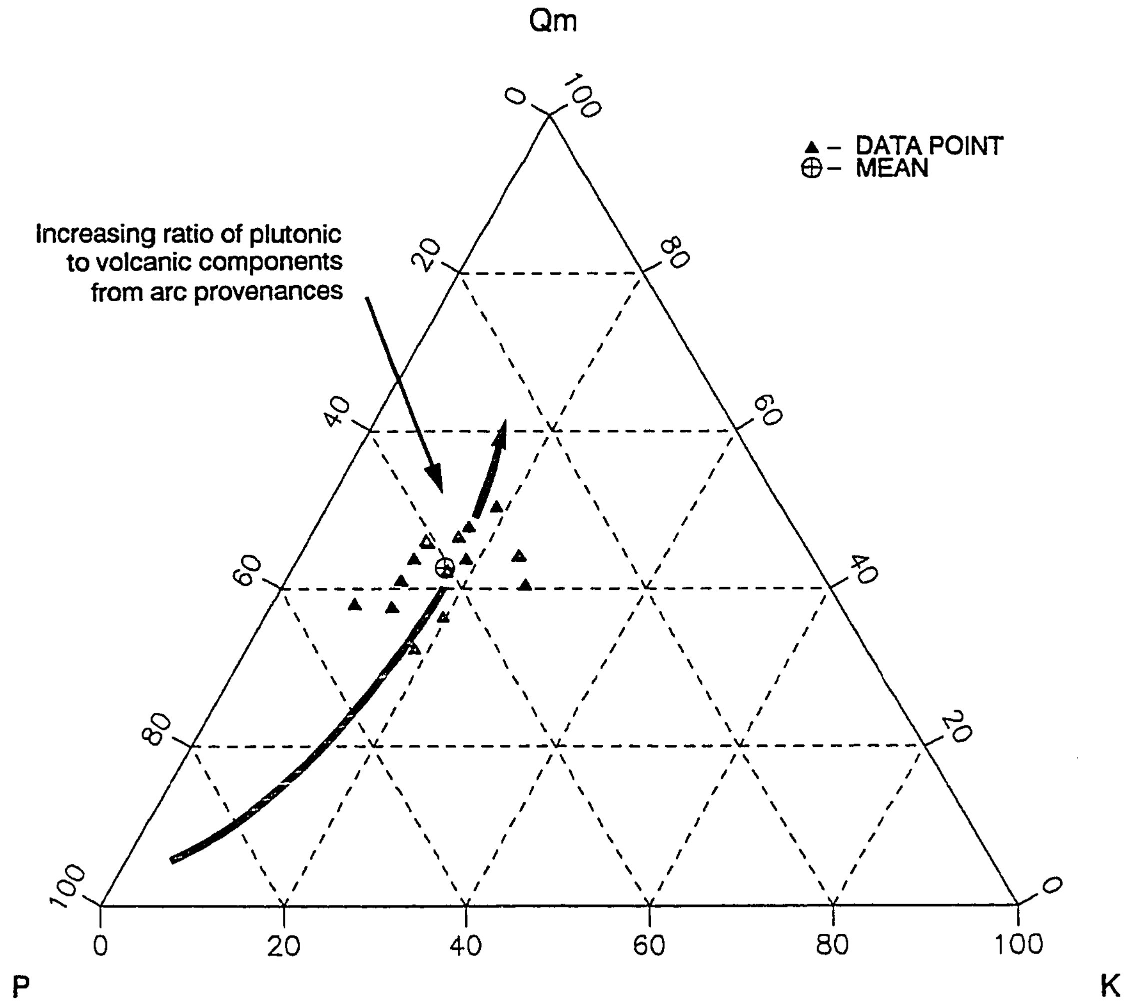


Figure 45. QmPK ternary plot from sandstone samples of the Guinda Formation (interpretation from Dickinson and Suczek, 1979).

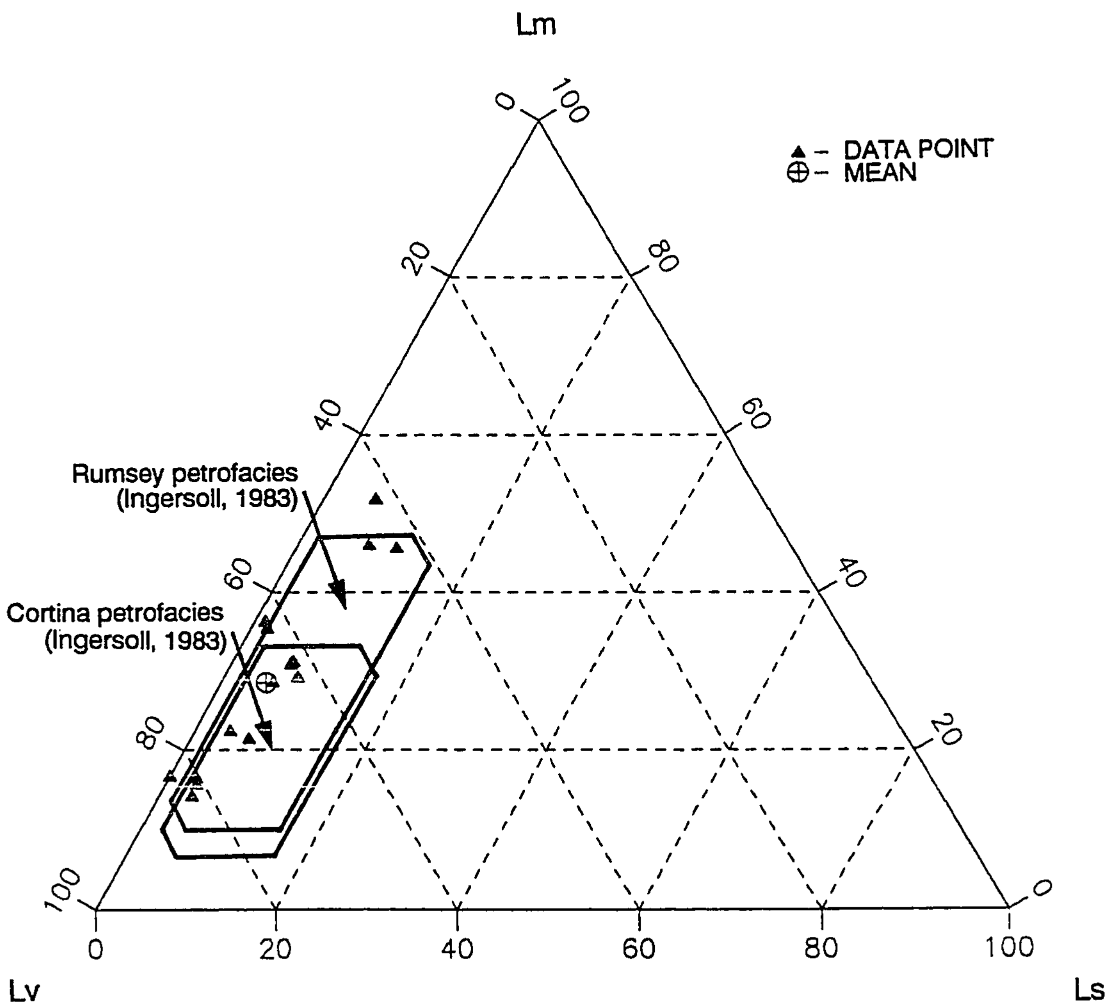


Figure 46. LmLvLs ternary plot from sandstone samples of the Guinda Formation.

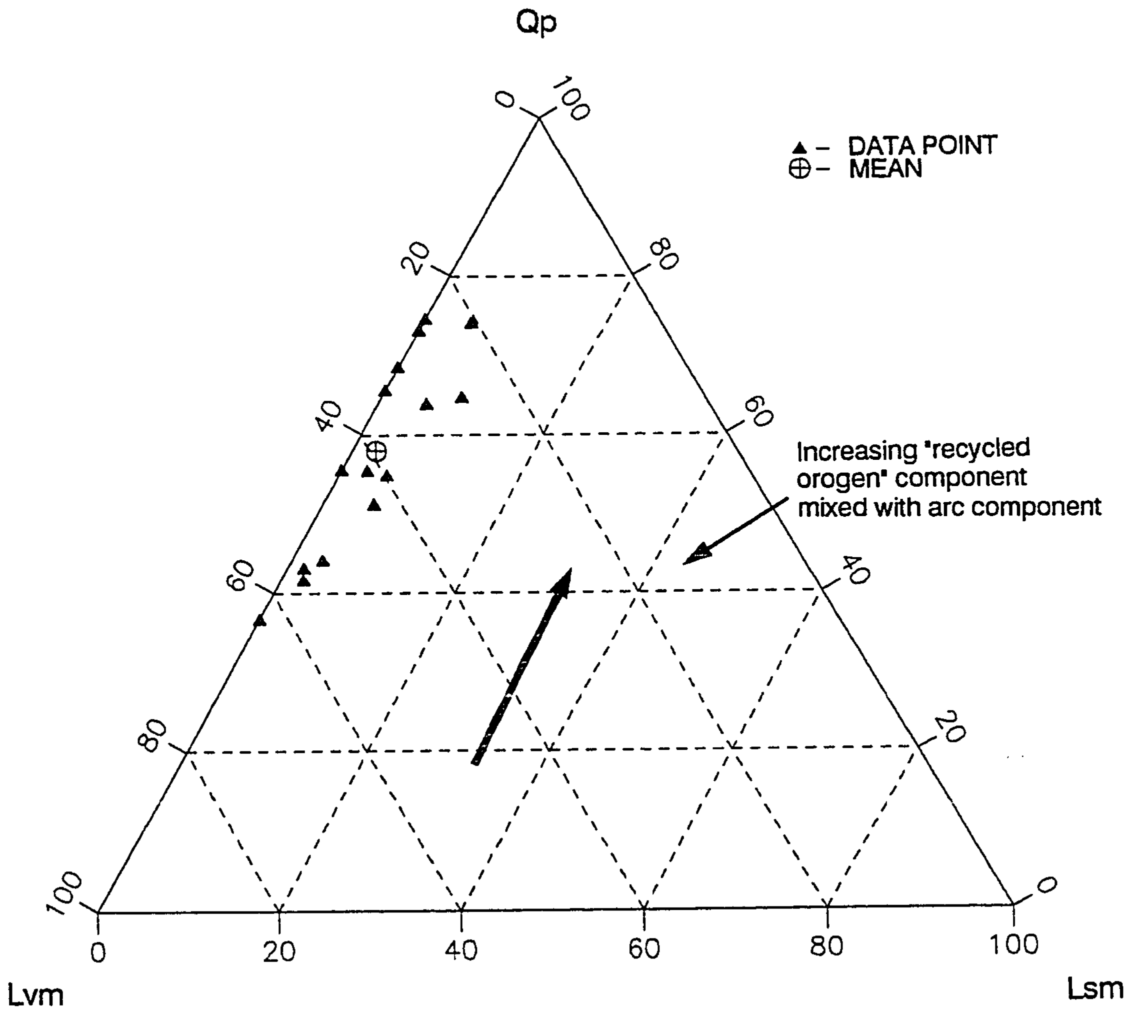


Figure 47. QpLvmLsm ternary plot from sandstone samples of the Guinda Formation (interpretation from Dickinson and Suczek, 1979).

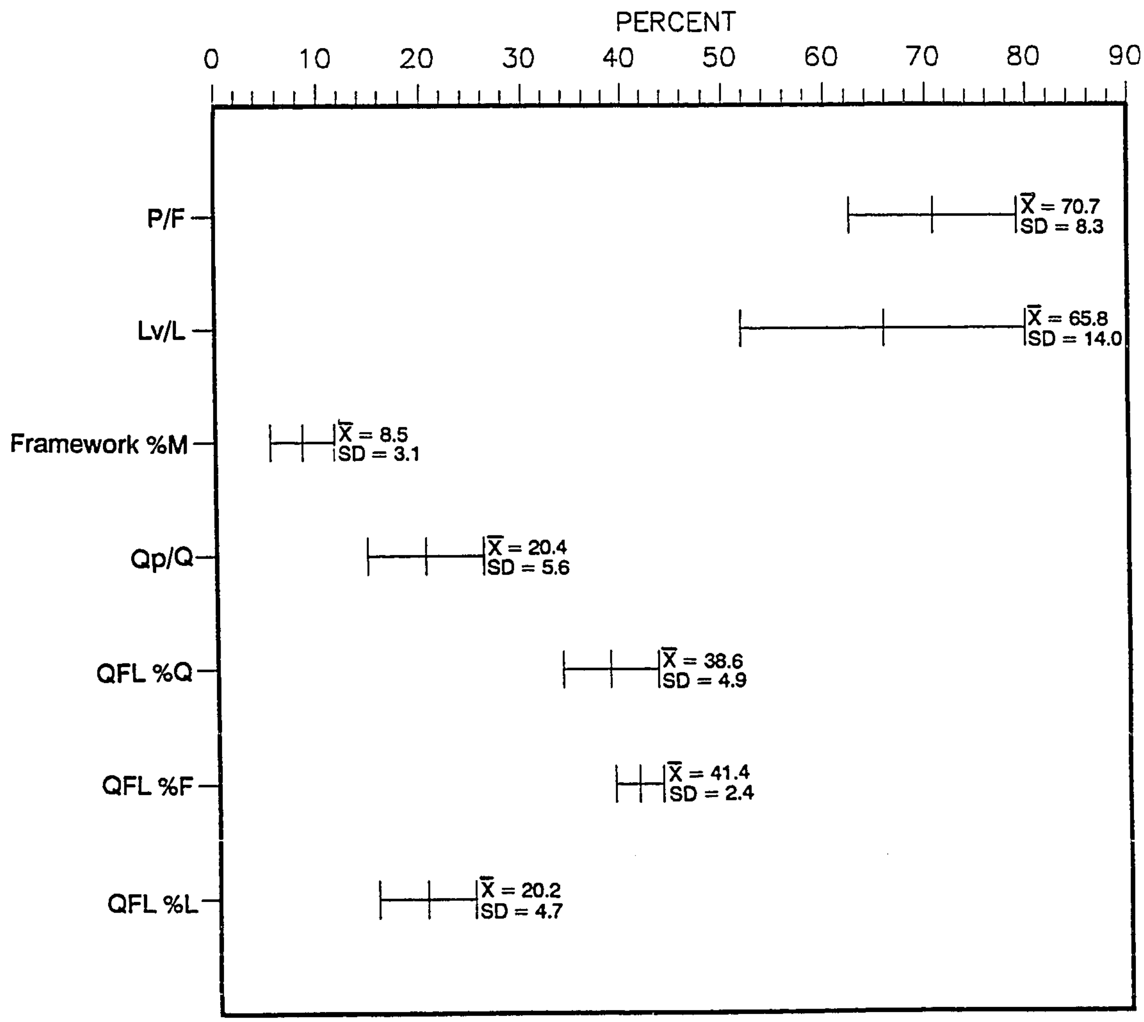


Figure 48. Means and standard deviations of selected framework parameters from sandstone samples of the Guinda Formation.

(fig. 43) and QMFLt (fig. 44) ternary plots indicate that these rocks were derived principally from a mature, dissected arc region (Dickinson et al., 1983). The general composition of the sandstones and a significant mica fraction (biotite-chlorite rich) in these rocks suggest that the provenance of the Guinda Formation was the Sierra Nevada plutonic arc system, and perhaps to a lesser extent the Klamath Mountains. A QmPK plot (fig. 45) shows that the Guinda Formation is relatively quartz rich; older rocks of the Great Valley Group are more lithic rich. The presence of a potassium feldspar-enriched sandstone also suggests an increased plutonic input into the Great Valley forearc system from a maturing arc. Also important is the significant, but not dominant, Lv fraction (fig. 46), suggesting that volcanism was active during deposition of the Guinda Formation. Ingersoll (1976) suggested that volcanism and the subsequent erosion of the volcanics were active during the Cathedral Range intrusive epoch that was occurring in the Sierra Nevada when the Guinda Formation was being deposited. This may explain the large amount of volcanic-derived sediment present in these rocks.

A plot of ratios of selected framework parameters (fig. 47) indicates that the Guinda Formation is relatively rich in Lvm and Qp (including chert). Ingersoll (1983) noted a "high-lithic" Rumsey petrofacies variant, similar to the Guinda samples, which may indicate addition of a local "metamorphic" component associated with the arc system. Such rocks may have been derived from erosion of Paleozoic and Mesozoic metamorphic-orogenic terranes that flanked the Sierra Nevada arc system on the west or the Klamath Mountains to the north.

Pebble Count

A pebble count was performed on a Facies A pebble and cobble conglomeratic sandstone located in the lower part of the Guinda Formation at the Putah Creek/Bray Canyon measured section. Ten randomly selected localities were selected for this count, and 50 clasts were counted at each location. Clasts are dominantly rounded to subrounded. The matrix is primarily coarse-grained sandstone. Clasts are mostly of volcanic and sedimentary origin; plutonic fragments are rare (table 10 and fig. 49). Of the sedimentary clasts, limestone clasts outnumber shale clasts by a ratio of 3:2. Rare sandstone clasts also are present. The limestone fragments consist of concretions or fragments of concretions, whereas the shale clasts are dominantly rip-ups. The volcanic clasts are mainly fine-grained microlitic types. The few plutonic rock fragments that are present are almost exclusively diorite. Rare red and black chert pebbles, comprising less than 0.5% of the total rock and therefore not counted, also occur in these rocks. Crude imbrication of the clasts that compose these

Table 10

Pebble-Count Data from the Conglomerate Near the Middle of the Putah Creek, North Side, Measured Section

SAMPLE (n=50/sample)	SEDIMENTARY CLASTS			TOTAL ROCK		
	SHALE (%)	SANDSTONE (%)	LIMESTONE (%)	SEDIMENTARY (%)	PLUTONIC (%)	VOLCANIC (%)
1	35.0	3.0	62.0	42.0	2.0	56.0
2	42.0	6.0	52.0	37.0	8.0	55.0
3	46.0	12.0	42.0	45.0	5.0	50.0
4	35.0	11.0	54.0	31.0	7.0	62.0
5	26.5	6.0	67.5	44.0	2.0	54.0
6	38.0	7.0	55.0	36.5	0.0	63.5
7	26.0	18.5	55.5	39.0	3.0	58.0
8	43.0	8.0	49.0	42.0	5.0	53.0
9	42.0	6.5	51.5	38.0	17.0	45.0
10	41.0	10.0	49.0	48.0	1.0	51.0
MINIMUM VALUE	26.0	3.0	42.0	31.0	0.0	45.0
MAXIMUM VALUE	46.0	18.5	67.5	48.0	17.0	63.5
SAMPLE MEAN	37.4	8.8	53.8	40.2	5.0	54.8
STAND. DEVIATION (±)	6.8	4.3	7.1	4.9	4.9	5.5

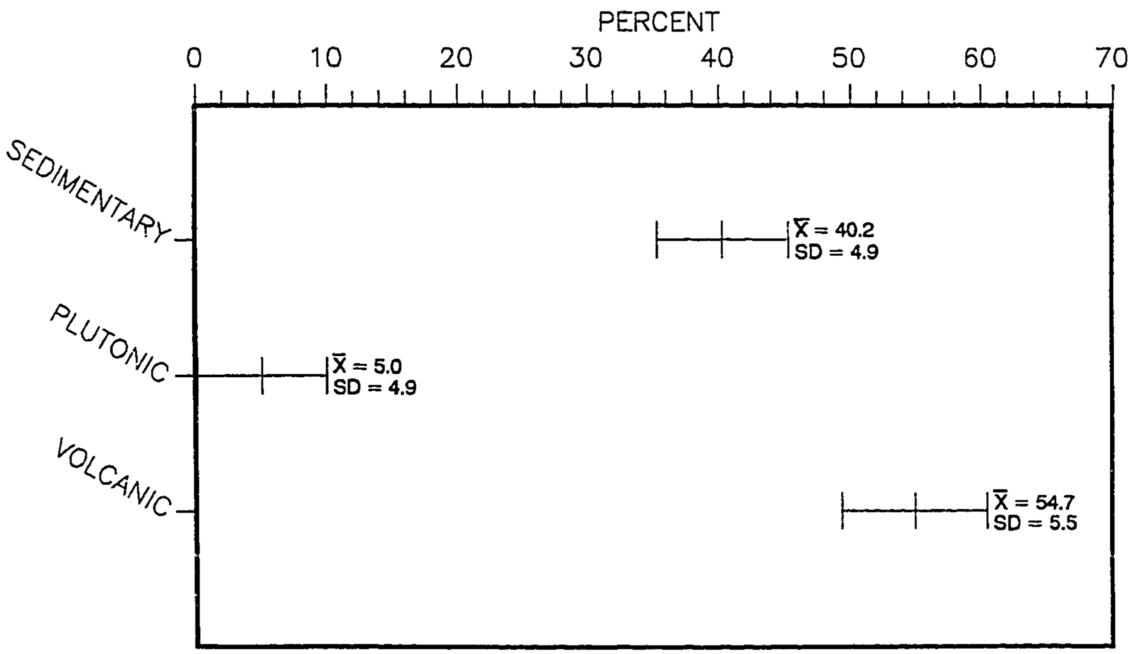


Figure 49. Means and standard deviations of sedimentary, plutonic, and volcanic clast percentages from the pebble-count data collected from the conglomerate near the middle part of the Putah Creek measured section.

conglomerates suggests a southward flow direction.

The durable clasts from the conglomeratic sandstone are dominantly rounded to subrounded, which implies significant transport and abrasion before introduction into the deep-water environment. The large number of shale clasts and other relatively soft rocks, that would normally not survive very long transport distances or an arduous route to their final resting place, suggests that transport distance for these clasts was relatively short.

The pebble-count data (fig. 50) imply derivation from a magmatic arc province, as defined by Bertucci and Ingersoll (1983). The high ratio of volcanic rocks to plutonic rocks suggests that arc volcanism was active during deposition of the Guinda Formation, even as dissection of the older plutonic roots of the arc terrane was in progress.

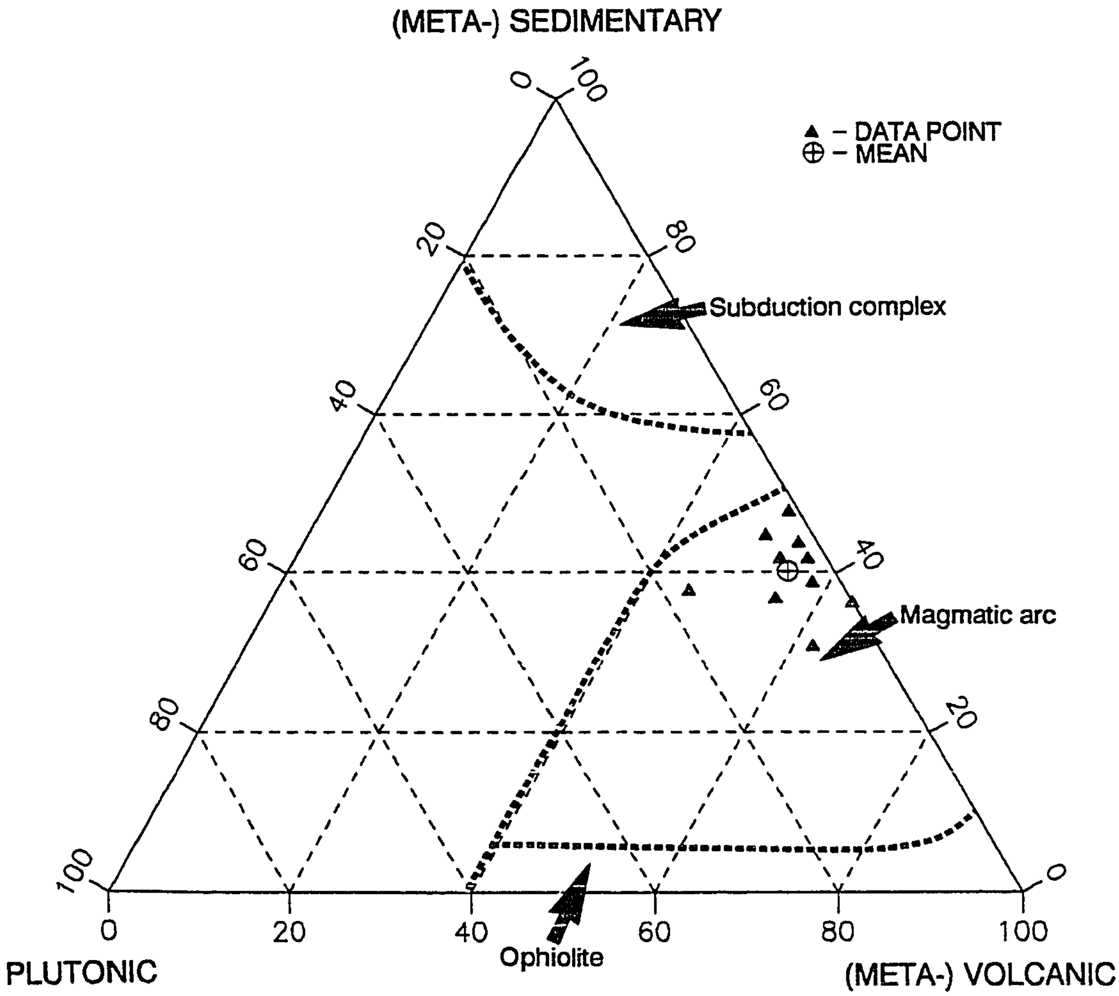


Figure 50. Ternary province diagram of pebble-count data taken from the conglomerate near the middle part of the Guinda Formation on the north side of Putah Creek (provenance zones from Bertucci and Ingersoll, 1983).

BIOSTRATIGRAPHY

Fourteen shale and claystone outcrop samples were washed and analyzed for foraminifera. Paleontological sample locations are shown on the geologic maps in the chapter on lithostratigraphy (figs. 7, 15, 20, 26, 30, 34). The paleontologic samples, their general location, and the general stratigraphic position from which they were retrieved are listed in Table 11. Identified fossils and their age and paleobathymetry are given in Appendix 3.

The number of specimens recovered ranges from a high of approximately 100 to a low of 1 per sample; 3 samples were barren. The lower, middle, and upper parts of the Guinda Formation yielded fossils, with the samples taken from the lower part containing the highest number.

Rare fragments of *Inoceramus naumanni* and *Baculites chicoensis* were recovered by the author from some of the finer-grained beds of the upper Guinda Formation at Black Butte Reservoir. Trace fossils, including grazing traces and some vertical and horizontal burrows, have been observed in shale and fine-grained sandstone beds throughout this formation.

Pyrite and pyritized radiolarians constituted the most abundant non-foraminiferal component in the samples. Carbonized wood fragments, mica, iron sulfide spheres, *Inoceramus* prisms, echinoid plates and spines, and various

Table 11

Locations and Stratigraphic Positions of Paleontologic Samples

SAMPLE ID	MEASURED SECTION	SAMPLE LOCATION	STRATIGRAPHIC POSITION
89-DBS-02SH	Black Butte Reservoir	SE SE sec. 31, T.23N, R.4W	Lower Guinda Fm.
89-DBS-03SH	Black Butte Reservoir	NE SE sec. 31, T.23N, R.4W	Upper Guinda Fm.
90-DBS-24SH	Black Butte Reservoir	NE SE sec. 31, T.23N, R.4W	Dobbins Shale Member
90-DBS-20SH	South Fork Willow Creek	SE NW sec. 9, T.19N, R.4W	Funks Fm.
90-DBS-27SH	South Fork Willow Creek	NE SE sec. 9, T.19N, R.4W	Dobbins Shale Member
90-DBS-34SH	Salt Creek, Capay Hills	SE SE sec. 33, T.13N, R.3W	Lower Guinda Fm.
90-DBS-37SH	Salt Creek, Capay Hills	SW SE sec. 34, T.13N, R.3W	Dobbins Shale Member
90-DBS-46SH	Bray Canyon, Putah Creek	SE SE sec. 21, T. 8N, R.2W	Lower Guinda Fm.
90-DBS-40SH	Bray Canyon, Putah Creek	SW SW sec. 22, T. 8N, R.2W	Upper Guinda Fm.
90-DBS-17SH	Ulatis Creek, Mix Canyon	NW SW sec. 34, T. 7N, R.2W	Lower Guinda Fm.
90-DBS-16SH	Ulatis Creek, Mix Canyon	NW SW sec. 34, T. 7N, R.2W	Upper Guinda Fm.
90-DBS-43SH	Alamo Creek, Gates Canyon	SE SE sec. 3, T. 6N, R.2W	Mid-Upper Guinda Fm.
90-DBS-44SH	Alamo Creek, Gates Canyon	SE SE sec. 3, T. 6N, R.2W	Upper Guinda Fm.
90-DBS-45SH	Alamo Creek, Gates Canyon	SE SE sec. 3, T. 6N, R.2W	Dobbins Shale Member

unidentified megafossil fragments also were present in these samples.

The preservation state of the microfossils is generally fair, with recovered specimens in varying states of dissolution. Tests of calcareous species, such as Nodosaria and Lenticulina, commonly are distorted and partially dissolved. Agglutinated, thick-shelled species, such as Dorothia and Haplophragmoides, commonly are in a much better state of preservation.

The vertical and lateral patchiness of recovered specimens tends to confirm the works of Pessagno (1976) and Douglas (1969) who noted the "feast or famine" nature of microfossils in the Guinda Formation. Several possible reasons for the paucity of microfossils in certain parts of the Guinda Formation exist: (1) syn- or post-depositional leaching of calcium carbonate-bearing organisms by rain or groundwater, (2) destruction of the fauna due to reworking of the sediment soon after deposition by either bioturbation or currents, (3) rapid deposition of sediment prohibiting development of a grazing fauna, (4) periods of adverse ecological conditions, and (5) biologic predation and scavenger ingestion of the microfauna soon after death.

Age Assignment and Sedimentation Rate

Specific ages assigned to the samples range from early Coniacian, within Goudkoff's G-2 foraminiferal zone, to the late Campanian E zone, with most samples clustered in the Santonian G-1 zone. The presence of the diagnostic benthic foraminifera *Cribrostomoides cretacea* in six samples, *Bermudezina uvigerinaeformis* in four samples, *Gaudryina pyramidata* in two samples, and *Eponides bandyi* in two samples, substantiates the belief that the Guinda Formation is Santonian in age, and affirms all recent biostratigraphic research that places the Guinda Formation near the middle of the G-1 zone (e.g., Berry, 1974; Almgren, 1986). The G-1 zone spans nearly the entire Santonian (fig. 4) from 87.5 Ma to 84.0 Ma (Kent and Gradstein, 1985). Both the Funks Formation and the Dobbins Shale Member of the Forbes Formation are included in the G-1 zone.

Ingersoll (1976) calculated an average sedimentation rate for the basin-plain environment in the Great Valley forearc basin, which includes the Funks Formation, at approximately 316 m/My (1035 ft/My). Trosper (1985) calculated the sedimentation rate for the lower Dobbins Shale Member of the Forbes Formation to be 340 m/My (1115 ft/My) based on detailed foraminiferal age control and stratigraphic thicknesses. Combined, the Funks Formation and the Dobbins Shale Member of the Forbes Formation are about 900 m (3000 ft) thick. Based on the sedimentation rates calculated by Ingersoll (1976) and Trosper (1985), it therefore would have taken approximately 2.8 My for these two units to accumulate, leaving approximately 0.7 My during the Santonian for deposition of the Guinda Formation.

Allowing time for accumulation of the Funks Formation and the Dobbins Shale Member of the Forbes Formation, indications are that deposition of the Guinda Formation occurred near the middle of the Santonian, beginning about 86.0 Ma and ending about 85.3 Ma. Research for this study indicates that the Guinda Formation averages about 200 m (700 ft) in thickness; therefore, the net-sediment accumulation rate for this unit is approximately 300 m/My (1000 ft/My). This value closely approximates the sedimentation rates calculated by Ingersoll (1976) for inner-, middle-, and outer-fan deposits that accumulated in the Great Valley forearc basin during the Late Cretaceous.

A sedimentation rate of 300 m/My (1000 ft/My) for the Guinda Formation appears anomalously low, especially when compared to the sedimentation rates calculated by Ingersoll (1976) and Trosper (1985) for strata deposited in the basin-plain environment. An explanation that would account for such a low net-sediment accumulation rate for the Guinda Formation is that the interval of time that the Guinda fans were inferred to be active may not be accurate. This time period may have been affected by an undetected hiatus in the stratigraphic record or from inaccuracies in the time scale associated with Goudkoff's G-1 zone. In addition, the influence of sediment compaction may play a much larger role than previously realized. After accounting for sediment compaction, sedimentation rates could have been 10 to 20% higher (Riecke and Chilingarian, 1974).

Paleobathymetry

Paleobathymetric calculations for the Guinda Formation were based on the types of foraminifera present in the samples and on the degree of dissolution of their calcite tests. In general, specimens recovered from the lower, middle, and upper portions of the Guinda Formation do not reflect paleobathymetric variability. The presence of *Bermudezina uvigerinaformis* in the upper Guinda Formation and lowermost Dobbins Shale Member of the Forbes Formation is a good indicator that these rocks were deposited at lower to upper abyssal depths (Trosper, 1985). *Cribrostomoides cretacea*, *Haplophragmoides*, and *Silicosigmoilina californica*, which occur in the Guinda Formation, are characteristic of the lower bathyal zone (Trosper, 1985); however, Ingersoll (1976) suggested that *Haplophragmoides* occurred in much shallower waters during the Cretaceous. Additionally, *Planulina* is characteristic of the middle bathyal zone, and *Bathysiphon* generally is restricted to the upper bathyal (Trosper, 1985). These data therefore suggest that deposition of the Guinda

Formation occurred primarily in middle- to lower-bathyal environments. Nyong and Olsson (1984), looking at Campanian and Maestrichtian deposits along the Atlantic side of the North American continental margin, place the bathyal zone at depths less than approximately 2500 m (8200 ft).

Deposition of the Guinda Formation may have been close to the calcium-carbonate compensation depth (CCD), but how close is open to speculation. Highly dissolved tests of planktonic foraminifera, indicative of deposition near the Santonian CCD, occur in several of the samples; however, it should be kept in mind that the degree of calcite dissolution is not by itself necessarily indicative of proximity to the CCD (Hay, 1970). Van Andel (1975) suggested that the Late Cretaceous CCD was about 4000 m (13,000 ft) below sea level in open-ocean conditions, whereas Ingersoll (1976) believed that the CCD may have been much deeper during this time. Detailed biostratigraphic data led Trosper (1985) and Trosper and Douglas (1985) to suggest that the Great Valley CCD in the latest Santonian was at a depth of about 3700 m (12,000 ft). These data suggest that deposition of the Guinda Formation occurred in water depths no deeper than about 3000 m (9800 ft).

WELL-LOG STUDY AND SUBSURFACE STRATIGRAPHY

Because the Guinda Formation is not an active target of the oil and gas industry, its subsurface extent is not well established. Only a few hundred of the nearly 8500 wells drilled in the Sacramento basin penetrate as deeply as the Dobbins Shale Member of the Forbes Formation, and far fewer were drilled into the Guinda Formation. With so few well penetrations, detailed subsurface mapping of the Guinda Formation and deeper units is difficult.

Correlation of the Guinda Formation throughout the basin proved to be difficult, not only because of the lack of good subsurface control, but also because this unit undergoes facies changes between opposite sides of the Sacramento basin. A typical log from a well located along the western margin of the Sacramento basin (fig. 51) shows the Guinda Formation with a "blocky" log motif, typical of a sand-rich channel sequence. In contrast, a typical log from a well located along the eastern margin of the Sacramento basin (fig. 52) typically shows the Guinda Formation with a "ratty" log signature, which is generated by alternating beds of coarse- and fine-grained clastic material.

The widely different log signatures of the Guinda Formation on the opposite sides of the Sacramento basin suggest strongly contrasting facies. Along the western

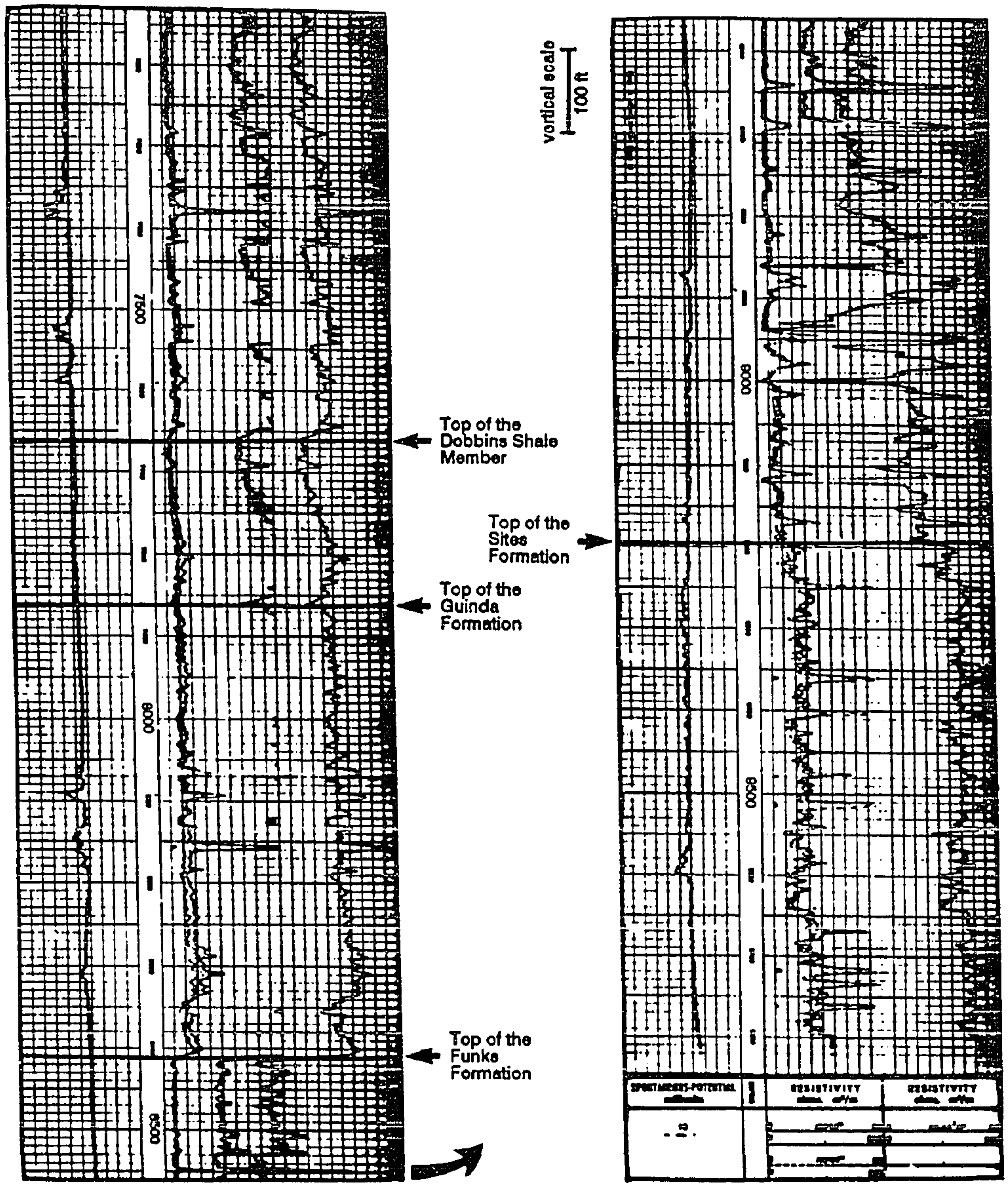


Figure 51. Typical electric log from a well located along the western portion of the Sacramento basin showing the Guinda Formation and adjacent units. Note the sharp boundary between the base of the sandstone-rich Guinda Formation and the top of the shale-rich Funks Formation. This log is from the Wallace R. Lynn et al. No. 1 well, operated by Exxon Corp. (sec. 24, T.16N, R.3W.).

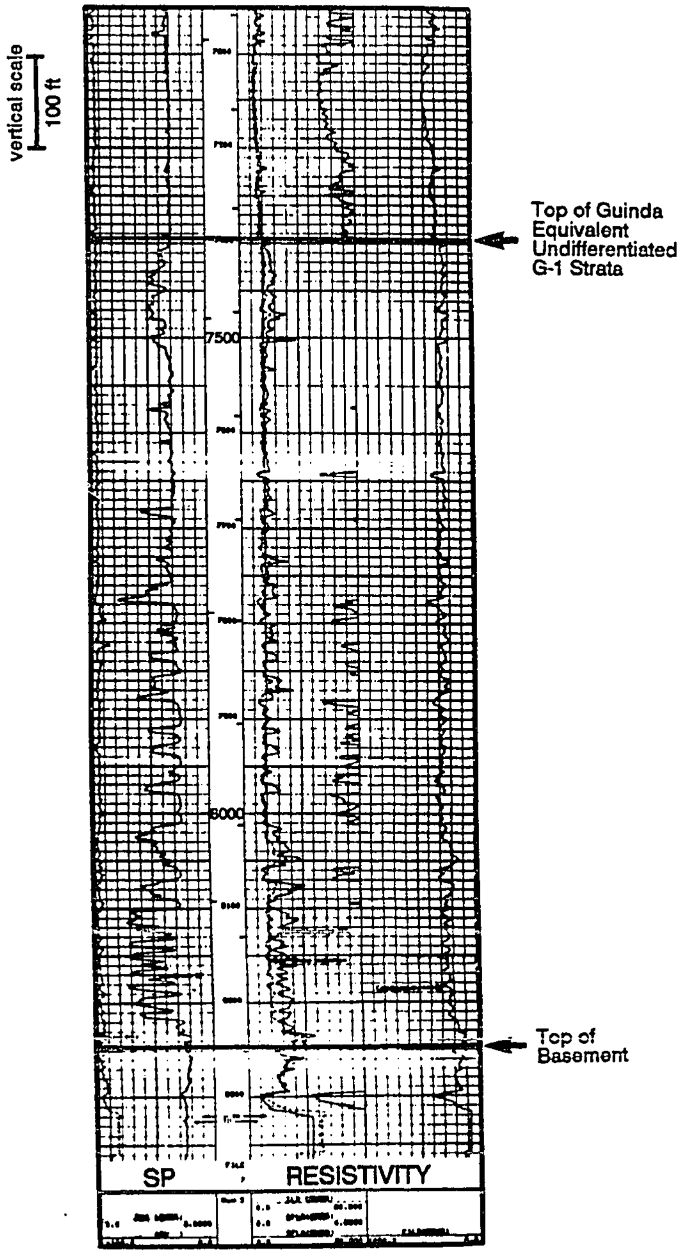


Figure 52. Typical electric log from a well located along the eastern portion of the Sacramento basin showing Guinda equivalent, undifferentiated G-1 strata and adjacent units. Note that these rocks rest nonconformably above basement rock of the Sierra Nevada and the log signature appears "ratty" due to alternating beds of sandstone and shale. This log is from Reichhold Energy Company's Bridge Heirs No. 1 well (sec. 1, T.13N, R.2E.).

portion of the Sacramento basin, the Guinda Formation records a deep-marine progradational event across the basin plain, whereas along the eastern part of the basin, a shallow-water, marine transgression across the shelf is suggested from faunal successions recorded in G-1 strata of the Chico Formation (Saul, 1959; Haggart, 1982, 1984; Russell et al., 1986a; Russell, 1987, 1988, 1990).

The Chico Formation is a thick, sandstone-dominated sequence of uppper Coniacian to lower Campanian rocks that were deposited in fluvial, deltaic, and shallow-marine environments (Haggart, 1982, 1984). Regional outcrop studies of the Chico Formation (Taff et al., 1940; Saul, 1959, 1961; Creely, 1965; Haggart, 1982, 1984; Russell et al., 1986a, 1986b; Russell, 1987, 1988, 1990), have only rarely addressed its subsurface extent.

The Chico Formation consists of, from oldest to youngest, the fluvial and fluvio-deltaic conglomeratic facies of the Ponderosa Way Member, the sandstone-dominated deltaic and shoreface facies of the Musty Buck Member, the shoreface and inner shelf deposits of the Ten Mile Member, the shale-rich outer shelf deposits of the Kingsley Cave Member (referred to as the "Massacre Cave" Member by Haggart (1982)), and the informally named Pentz Road member, which consists largely of shallow-marine and estuarine deposits. The Upper Cretaceous outcrops in the Pentz area, which were mapped by Creely (1965), comprise the southernmost occurrence of the Chico Formation.

Coeval with deposition of the Guinda Formation are the Ten Mile and the Kingsley Cave members. The Ten Mile Member generally consists of erosively based beds of fine-grained, hummocky cross-stratified sandstone. Bioturbation is common in this member, and basal shell-lag deposits of storm-surge origin contain a diverse marine fauna. The Kingsley Cave Member commonly consists of parallel-laminated to highly bioturbated mudstone and siltstone with an Inoceramus-dominated fauna (Haggart, 1982, 1984).

Regional outcrop studies of the Chico Formation, as well as detailed subsurface geologic work conducted by D.P. Imperato (oral comm., 1990) along the eastern portion of the northern and central Sacramento Valley, tend to support the idea that over time, the fluvio-deltaic system that fed the developing Chico Formation was transporting some of the sediment shed from the volcanic highlands of the ancestral Sierra Nevada into the Great Valley forearc basin.

Delineating the contrasting facies of the Guinda and Chico formations in the subsurface can prove difficult due to the lack of subsurface continuous cores and detailed well logs. Because of this, all subsurface strata of G-1 age have traditionally been referred to as the "Guinda Formation," whereas surface exposures along the eastern portion of the Sacramento basin typically are referred to as the "Chico Formation."

It is the author's belief that G-1 strata in the subsurface should be differentiated and referred to as either the Guinda Formation or Chico Formation based on their contrasting facies. Thus, any sandstone-rich unit of G-1 age in the subsurface should be called "Chico Formation" if it has facies typical of outcrops of the Chico Formation. This would include rocks of deltaic, shoreface, and shelf origin. Similarly, any sandstone-rich G-1 strata in the subsurface that have characteristics of a deep-marine fan system should be designated as the "Guinda Formation." If the facies of any of these rocks are unknown, then they could be referred to as "undifferentiated G-1 strata."

A few cores have proven to be useful in the recognition of the Chico Formation in the subsurface. A stratigraphic test well drilled in 1952 south of Sutter Buttes (sec. 31., T.14N., R.2E.) by Shell Oil Company retrieved continuous core from a unit originally described as the Guinda Formation. Although this core is unavailable for inspection, core descriptions made by Shell and the corresponding well log (fig. 53) indicate that the unit is a calcite-cemented conglomerate with a poorly sorted sandstone to siltstone matrix, interbedded with sandstone and siltstone. The clasts were described as very well rounded, poorly sorted, and composed of gabbro, chert, and

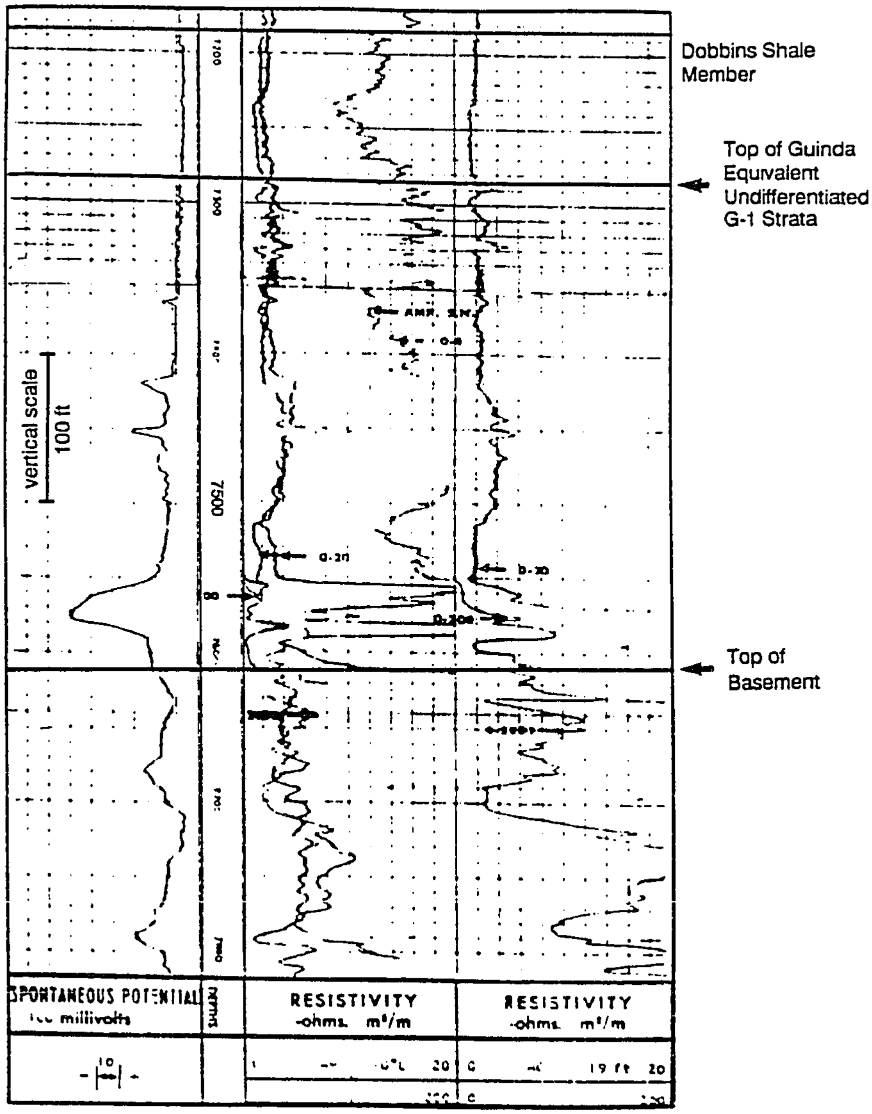


Figure 53. Well log from Shell Oil Company's Stratigraphic Test No. 1 well (sec. 31, T.14N., R.2E.) showing a sandstone-dominated unit of G-1 age resting nonconformably on basement rock of the Sierra Nevada.

granodiorite. In addition, numerous megafossil fragments (including <u>Ostrea</u>) and rare lignitized wood fragments were found in some intervals. Such lithologically distinctive rocks are interpreted to belong to the Chico Formation rather than to the Guinda Formation because interbedded conglomerates, sandstones, and shales, nonconformably overlying the basement rock of the Sierra Nevada, crop out as the Chico Formation along major streams that cut the western foothills of the northeastern Sierra Nevada.

In the same area that the stratigraphic test core was retrieved, subsurface work with well-logs indicates the presence of a sandstone-dominated unit that does not appear to be part of the Guinda deep-marine, submarine-fan system that is located along the western portion of the basin. These rocks, located in the Tisdale Gas Field southwest of Sutter Buttes, range in thickness from less than 60 m (200 ft) to just under 300 m (1000 ft) over a very short distance (less than 1.5 km (1 mi)). The variability in thickness of these undifferentiated G-1 rocks appears to be dependent mostly upon whether this unit is veneered over structural highs in the basement, where stratigraphically thin undifferentiated G-1 strata are present, or if the unit fills adjacent structural lows in the basement, where the undifferentiated G-1 rocks are much thicker. This relationship suggests that, during deposition of the these rocks, the Sierra Nevada was tectonically active and was dominated by a series of upthrown and downthrown fault blocks that may have influenced depositional patterns and partially controlled progradational patterns of the Guinda fans.

Correlation of well logs from the western portion of the basin, where the presence of the Guinda Formation is well established, to the eastern portion of the basin, where the Chico Formation is present, allows a crude delineation of the transition between the Guinda and Chico formations in the subsurface. The transition between the Guinda and Chico formations must occur just east of the depositional axis of the basin (fig. 54). Strata located to the west of the transition line are attributable to the deep-marine, sandstone-rich G-1 rocks of the Guinda Formation, and those to the east of this line are attributable to the shallow-marine rocks of the Chico Formation.

The structural axis of the basin deepens towards the south, with the top of the undifferentiated G-1 rocks at over 14,000 ft (4250 m) in the southern part of the basin. In the deep part of the southern Sacramento basin, several wells have penetrated sandstone-rich units that are referred to by workers in this area as "undifferentiated G-1 strata." Examples of this are the HBC-Edwards #1-17 well (sec. 17, T.7N, R.5E.), and the Young Community #1 well (sec. 34, T.3S., R.8E), which encountered G-1 strata at a

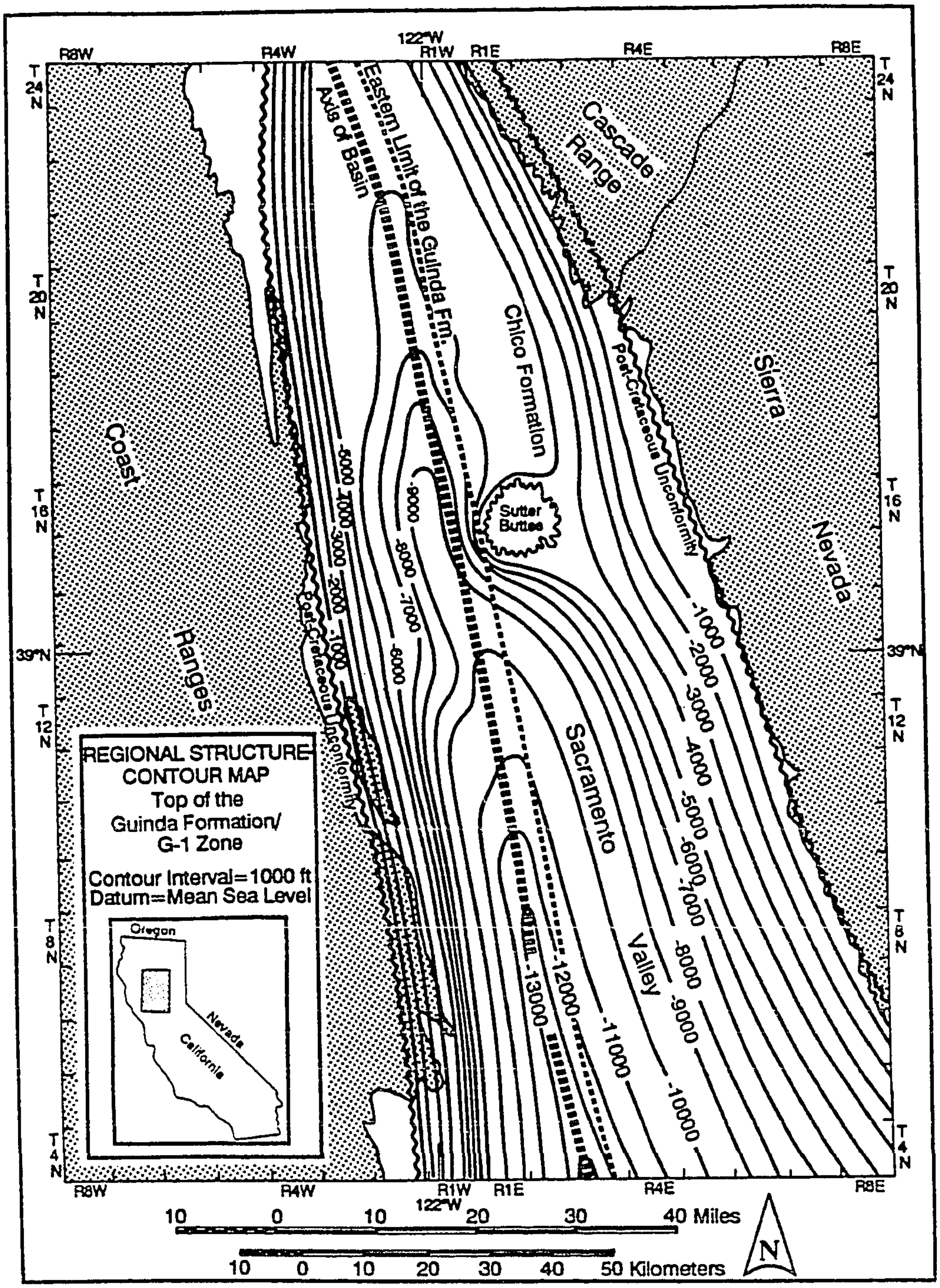


Figure 54. Generalized structure-contour map on the top of the Guinda Formation/undifferentiated G-1 zone and the approximate eastern limit of the Guinda Formation.

depth of 3979 m (13,055 ft). It is unclear whether these rocks are part of the Guinda Formation, Chico Formation, or some other stratigraphic unit of the same age.

PALEOGEOGRAPHY AND DEPOSITIONAL MODEL

Tectonic Setting and Regional Stratigraphy

The plate tectonic setting and regional stratigraphy of the Upper Cretaceous Great Valley forearc basin have been well established by previous work (e.g., Dickinson and Rich, 1972; Dickinson and Ingersoll, 1978; Dickinson and Seely, 1979; and Ingersoll, 1976, 1982, 1983). Despite all that has been written on these subjects, however, a specific paleogeographic and depositional model for the Guinda Formation has never before been proposed. Documentation and interpretation of the data presented in this study now allow the history of this unit to be unraveled.

Hemipelagic mud and silt, represented by the Funks Formation, accumulated for a relatively long period prior to progradation of the deep-sea Guinda fan system. Apparently, this progradational event occurred in the Santonian, beginning approximately 86.0 Ma and lasting for approximately 0.7 My. The north-south trending Great Valley forearc basin was well-developed during this time and was relatively deep (Ingersoll, 1976, 1983). Micropaleontological data suggest a depth approaching 3000 m (10,000 ft) prior to formation of the fan system (Trosper, 1985).

The petrographic data strongly suggest that the sediment composing the Guinda fan system was derived principally from erosion of the Sierra Nevada at a time when volcanoes were active. Tectonic events associated with emplacement and subsequent erosion of the Cathedral Range intrusives (Ingersoll, 1976) may have resulted in eventual transport of large amounts of sediment to the basin, subsequently causing progradation of the Guinda fan system. Although the composition of the sediment permits the possibility that some sediment was supplied by the older Jurassic magmatic arc of the Klamath Mountains terrane, the chief source area appears to have been from the Sierra Nevada.

It does not appear that deposition of the Guinda fan system was associated with a eustatic lowering of sea level, because work by Haq et al. (1987) indicates that sea level was relatively stable and rising moderately during the Santonian; rather, it seems that the influx of sediment into the basin led to progradation of the Guinda fan system over the Funks Formation. Initial progradation of the Guinda fans is indicated by the stacked outer-fan depositional lobes over fan fringe and basin-plain deposits, especially well shown at the Black Butte Reservoir and Gates Canyon measured sections. Stratigraphic work along the western margin of the Sacramento basin reveals that, as the fan system pushed farther into the basin, the basin plain and outer-fan deposits were covered by middle-fan channel and interchannel deposits.

The bimodal nature of the paleocurrent data, suggesting transport towards the south and west, implies that progradation of the Guinda fan system occurred both across the basin and longitudinally. This could have been accomplished if the Great Valley forearc basin plunged at a low angle in a southerly direction, as has been suggested by Ingersoll (1976). Micropaleontologic data suggest that the deeper parts of the forearc basin, located in the present southern Sacramento basin, approached 3000 m (10,000 ft) (Trosper, 1985), and a northern shoreline was present near the city of Redding (Haggart, 1986b), where shallow-marine shelf rocks are overlain by nonmarine strata of Santonian age. Thus, the distance between the northern shoreline and the deeper parts of the forearc basin would have been about 300 km (190 mi) and would have sloped at approximately 0.7° towards the south. This evidently was sufficient to cause sediment to be transported laterally across the basin floor or for it to be deflected to the south.

Basement tectonics also apparently influenced the deposition of G-1 strata. This is suggested by extreme thickness fluctuations observed on well logs between closely spaced wells that penetrate G-1 strata that onlap the Sierra Nevada along the eastern side of the Sacramento basin.

Fan Model

Several different fan models have been proposed to reflect different morphologies and vertical sequences (figs. 55 and 56) observed in deep-sea fans. The Guinda fan system most closely approximates a mixed-sediment fan system (Nelson and Nilsen, 1984), with the possible exception of the fan(s) represented in the Salt Creek area, which more closely approximates a sand-rich fan system (Nelson and Nilsen, 1984). Exposures along the sandstone-dominated Salt Creek section suggest a fan that was composed of a thick series of dominantly amalgamated channels.

Depositional Setting

During the time that the Guinda Formation was being deposited, an east-west transect across the Sacramento basin would have shown a facies transition from a fluvial-deltaic environment in the extreme eastern part of the basin, grading westward into shelf and slope deposits, and eventually into deep-marine turbidites. The fluvial-deltaic, shelf, and slope environments are presently preserved in the middle portion of the Chico Formation, whereas the deep-marine turbidites constitute the Guinda

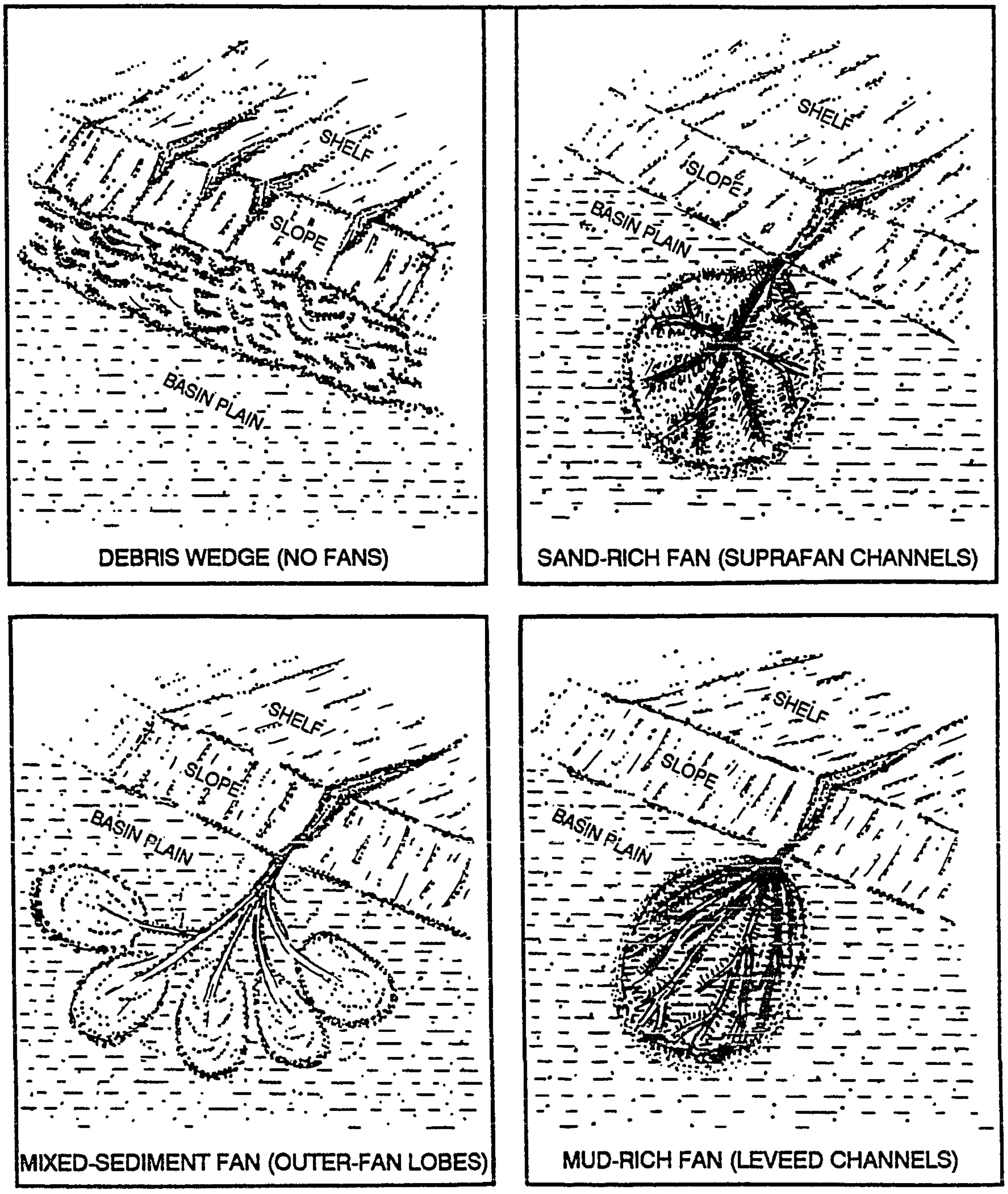


Figure 55. Morphology of various deep-sea fans (modified from Nelson and Nilsen, 1984).

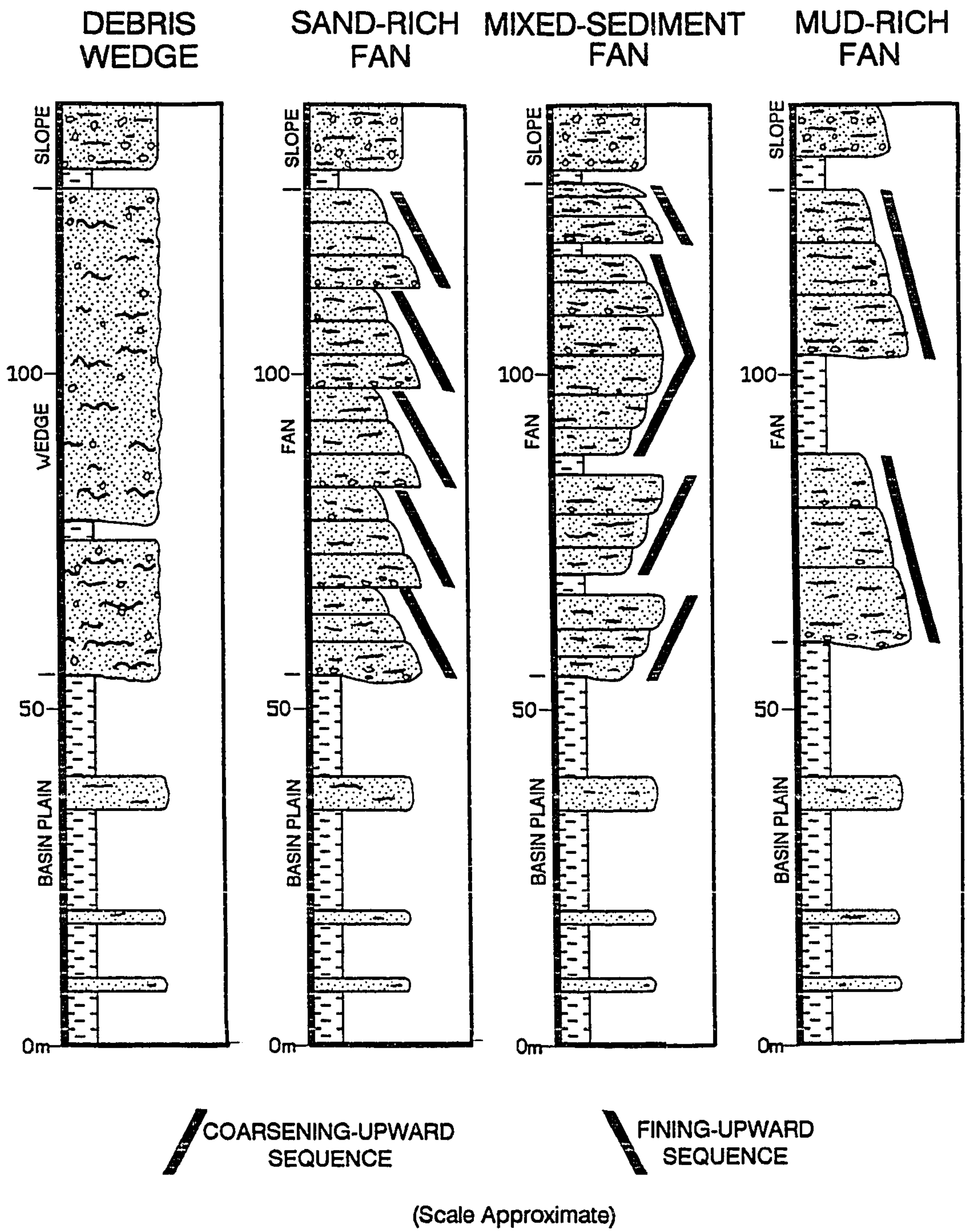


Figure 56. Idealized vertical sequence through various deep-sea fan accumulations (modified from Nelson and Nilsen, 1984).

Formation.

As the Chico deltaic system supplied vast amounts of sediment to the basin during the Santonian, the slope environment became dissected by a series of canyons that funneled the sediment to the basin floor and fed the submarine Guinda fan system. During this time, a relatively wide shelf occupied the Santonian continental margin along the western edge of the northern and central Great Valley forearc basin. This is suggested by the large distance of up to 50 km (30 mi), perpendicular to depositional strike, between the ancient shoreline sediments, which today are preserved as the Ponderosa Way Member of the Chico Formation (Russell et al., 1986a), and the deep marine sediments that presently form the Guinda Formation. The formation and filling of deeply incised canyons into the slope environment, one of which is today preserved by the Kingsley Cave Member of the Chico Formation (Haggart, 1984, 1986), may have resulted in a large number of smaller fan systems that migrated rapidly across the basin plain. A paleogeographic reconstruction of the Guinda fan system is shown in Figure 57.

The sediment that fed the Guinda fan system was eventually cut off, and deposition of the basin-plain Dobbins Shale Member of the Forbes Formation began. Why the fan-feeding sediment supply was terminated at this time is unclear. Cessation of transport of sediment to the

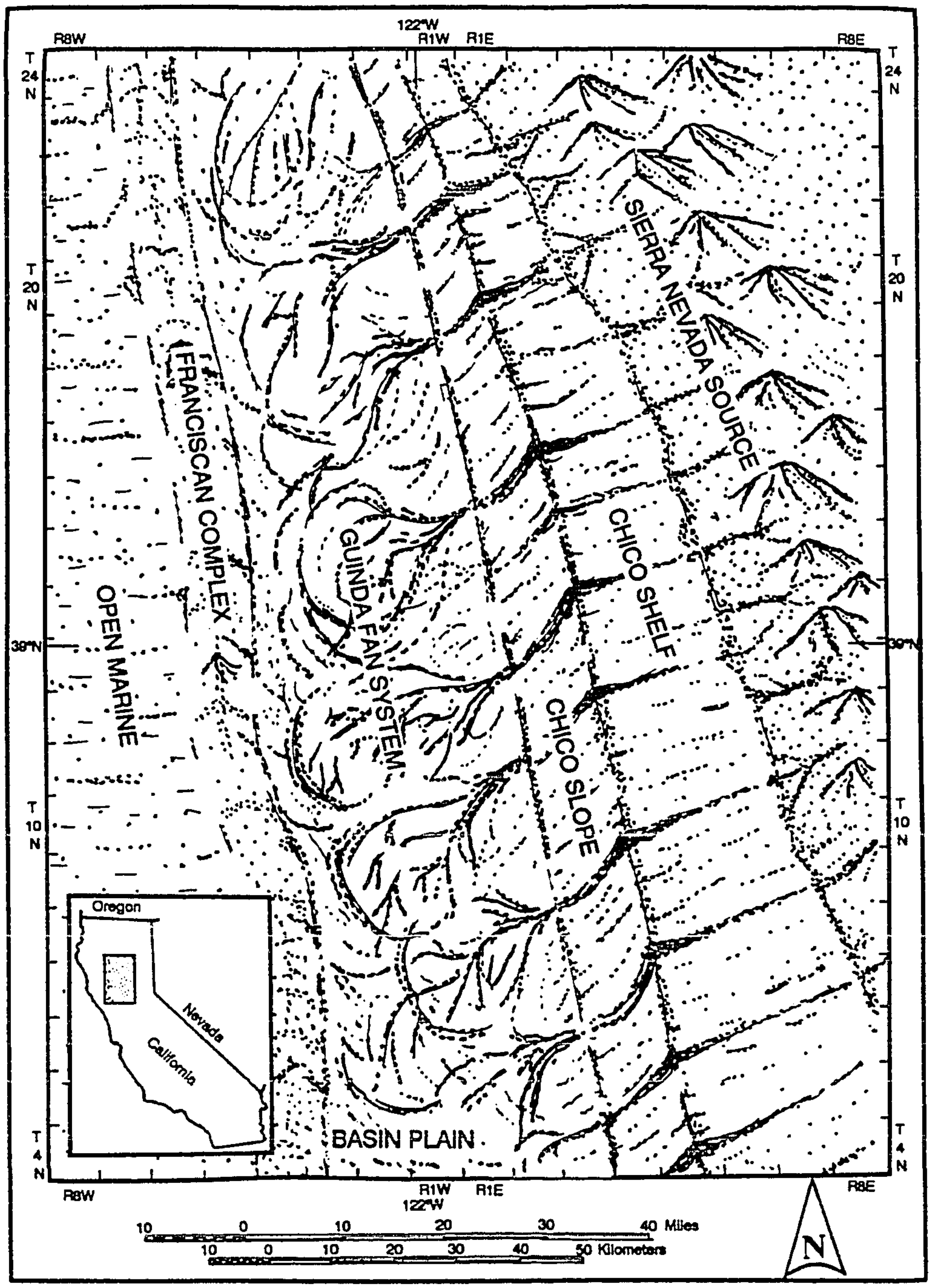


Figure 57. Paleogeographic reconstruction of the Guinda Formation during the late stages of its development.

Guinda fan system may have been caused by land subsidence induced by the eastward migration of the Sierra Nevada magmatic activity or by the changing patterns of on-land depositional supply and fluvial patterns.

Modern Analog

A modern forearc basin, the North Luzon Trough, located east of the Philippines adjacent to the Mindanao Trench (Lewis and Hayes, 1984), provides a suitable modern analog to the Cretaceous Great Valley forearc basin because the geometry and dimensions of the two are similar. In this modern system, continental crust lies behind an active volcanic arc, and there is a deep forearc basin, an outer-arc ridge, and an active subduction zone. The thickest sediment is in the outer part of the forearc basin, and thin sediment onlaps the magmatic arc. Sediment is being supplied into the North Luzon Trough at a high rate (Lewis and Hayes, 1984), although unlike the Guinda Formation, the sediment is mud rich, rather than sand rich. Net accumulation of Neogene sediment in the forearc basin is about 3950 m (13,000 ft), which is similar to that which accumulated in the Sacramento basin.

Seismic data interpreted by Lewis and Hayes (1984) reveal that progradation and migration of fans in the North Luzon Trough over time have resulted in a complex depositional pattern. These fans have been built axially along the floor of the forearc basin, and a strong transverse component also is suggested. This fan system exhibits multiple current directions with substantial sediment mixing. This setting is somewhat analogous to the fan system that formed the Guinda Formation, where bimodal paleocurrents and generally homogeneous petrographic data are indicative of regional mixing of sediment prior to its final deposition.

HYDROCARBON POTENTIAL

Campanian, Maestrichtian, and certain Tertiary units in the Sacramento basin have produced prolific amounts of natural gas, but strata older than the Forbes Formation, including the Guinda Formation, have remained largely unproductive. Yet numerous gas seeps occur from the Guinda Formation, for example, along the Salt Creek section located in the Capay Hills. Similarly, older strata of the Great Valley Group contain numerous gas, and in places, oil seeps (Graham, 1981).

Only two wells have produced gas from the Guinda Formation, both located along the western margin of the Sacramento basin and both having produced from stratigraphic traps (California Division of Oil and Gas, 1982b). The California Division of Oil and Gas (1982a) also reported that a gas field consisting of one well that was never brought on line, Nicolaus Gas Field (sec. 5, T.11N., R.4E.), contains commercial quantities of gas from the Guinda Formation. However, due to this field's proximity to the eastern margin of the Sacramento basin where the Guinda Formation is not present, it appears that the gas may instead be originating from the Forbes Formation or Chico Formation.

One of the wells that produced commercial quantities of gas from the Guinda Formation is General Petroleum

Corporation's (Mobil Oil Corporation) Wolcott-Capitol No. 1 well (sec. 13, T.19N., R.2W.) located in the Willows-Beehive Bend Gas Field. This well produced an average of 280 thousand cubic feet of gas per day (MCF/day) from about 70 ft (21 m) of clean sandstone at a depth between 7230 and 7425 ft (2204 and 2263 m) (fig. 58). The other well that produced commercial quantities of gas from the Guinda Formation is located in the Bounde Creek Gas Field. B.B.B. Oil Enterprise's McHatton No. 1 well (sec. 1, T.18N., R.2W.), produced gas from approximately 35 ft (11 m) of clean sandstone at a depth between 6965 and 7100 ft (2123 and 2164 m) (fig. 59). Gas production from this well averaged 1848 MCF/day when it was in operation.

The reason that there are not more wells producing gas from the Guinda Formation appears to be due to inadequate testing of this unit, because other variables favorable for the accumulation of natural gas appear to exist. Only a small number of wells scattered throughout the basin have been drilled into the Guinda Formation, leaving large amounts of strata largely unexplored. With such limited drilling, the possibility exists that undiscovered gas reserves are present in this unit.

Research conducted by Graham (1981) indicates that the Guinda Formation did not miss the gas window during burial. Also, although low permeabilities have been reported for these rocks (Morrison et al., 1972), it does

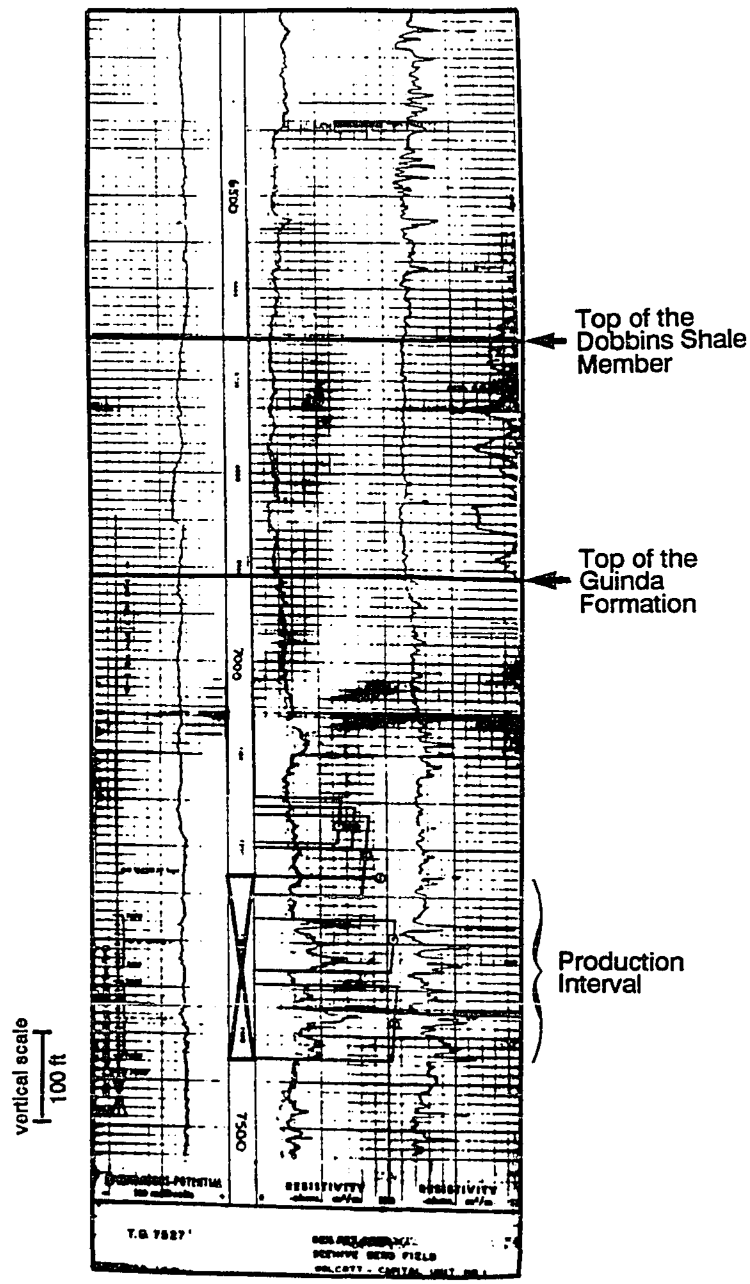


Figure 58. Electric log showing the production interval from General Petroleum Corporation's (Mobil Oil Corporation) Wolcott-Capitol No. 1 well (sec. 13, T.19N., R.2W.), in the Willows-Beehive Bend Gas Field. Gas production occurred from the Guinda Formation at a depth between 7230 and 7425 ft (2204 and 2263 m).

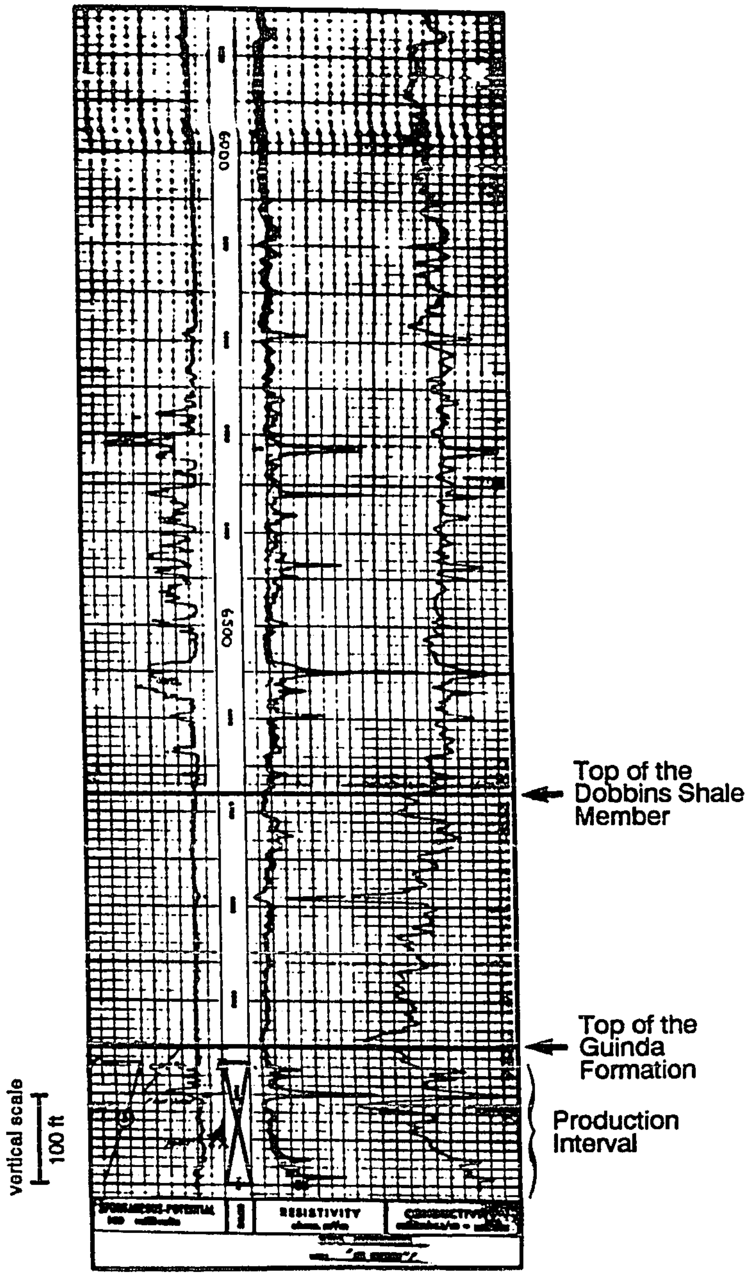


Figure 59. Electric log showing the production interval from B.B.B. Oil Enterprises's McHatton No. 1 well (sec. 1, T.18N., R.2W.), in the Bounde Creek Gas Field. Gas production occurred from the Guinda Formation at a depth between 6965 and 7100 ft (2123 and 2164 m).

not appear that they are low enough to inhibit the movement of gas. Potential source rocks for gas in the Guinda Formation include the underlying shale-rich Funks and Yolo Formations. It is possible, however, that any gas that was initially trapped in this unit may have leaked out and migrated to overlying units.

CONCLUSIONS

The Guinda Formation composes part of the Great Valley Group that crops out in a narrow band along the eastern margin of the northern Coast Ranges from just west of Vacaville to Black Butte Reservoir, a distance of nearly 300 km (180 mi). The Guinda Formation also underlies the western half of the Sacramento basin. In places it approaches 300 m (1000 ft) in thickness, but it averages about 200 m (700 ft) along the western margin of the basin.

Micropaleontologic work confirms that the Guinda Formation was deposited during the Santonian, and it represents part of Goudkoff's G-1 foraminiferal zone. The Guinda Formation was deposited in middle- to lower-bathyal environments above the CCD in waters no deeper than about 3000 m (10,000 ft). Sediment accumulation rates are placed at about 300 m/My (1000 ft/My) based on the estimate that deposition of the fan system lasted about 0.7 My.

The Guinda Formation records the progradation of a submarine fan system longitudinally and laterally across the Great Valley forearc basin. The Guinda Formation is genetically related to parts of the Chico Formation, which records relatively shallow-water marine deposition on a shelf. In the subsurface, the Guinda and Chico formations are distinguished by their contrasting facies on geophysical well logs.

Subsurface work from core and geophysical well logs indicates that in the eastern portion of the Sacramento basin undifferentiated G-1 strata onlap the Sierra Nevada basement. This occurs just east of the basin axis. Widely variable thicknesses of the Guinda Formation in areas where this formation is in nonconformable contact with the basement suggest that the Sierra Nevada may have been tectonically active during deposition of the Guinda fan system; structures formed at this time probably influenced the depositional pattern of the Guinda fan system.

Petrographic data indicate that the Guinda sandstones are compositionally immature to submature, matrix rich, and moderately sorted. The grains are subangular to subrounded, and the rocks have undergone significant mechanical and chemical compaction. Thin-section modal analyses confirm that the Sierra Nevada was the most likely source of these rocks, although metamorphic lithic fragments present in these rocks suggest that the Klamath Mountains also may have contributed a minor amount of sediment into the basin. A significant volcanic fraction in these rocks suggests that volcanoes were active in the Sierra Nevada during the time that the Guinda Formation was being deposited. There is a remarkable similarity among the analyses of framework grains from samples taken vertically and along strike of the Guinda Formation, indicating that the sediment was well mixed. Perhaps sedimentologic mixing occurred both on the Chico shelf and in the Guinda fan system. Paleocurrent data indicate bimodal current directions, one oriented towards the south, and the other towards the west. These data suggest that the fans prograded both westward across the basin and southward along the basin axis.

Detailed stratigraphic work conducted on these rocks reveals them to be stratigraphically highly variable along strike, and to consist primarily of middle-fan and outer-fan facies associations. The Guinda Formation most closely approximates a mixed-sediment fan system. Average thickness of the fan system is about 200 m (700 ft); the thickness rarely exceeds 300 m (1000 ft).

Lack of adequate testing of the Guinda Formation appears to be the main reason for the low hydrocarbon productivity of these rocks because other variables favorable to the accumulation of natural gas appear to be present. Other reasons for the apparent lack of hydrocarbons in this unit may be related to the lack of suitable source rocks, inadequate or leaked hydrocarbon traps, or permeability barriers.

This study demonstrates the usefulness of employing stratigraphic, petrographic, and paleontologic data to decipher a complex geologic system like the Guinda Formation. Nevertheless, additional work is needed that addresses the close relationship between the Guinda and

Chico formations and their relationship with the Sierra Nevada source terrane. Such research would further enhance our understanding of the Cretaceous Great Valley forearc basin of California, currently one of the most studied ancient forearc systems in the world.

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APPENDIX 1

MEASURED SECTIONS

EXPLANATION OF MEASURED SECTIONS

ROCK TYPE

SHALE

SILTSTONE

SANDSTONE

CONGLOMERATE WITH SANDSTONE MATRIX

INTERBEDDED SHALE AND SANDSTONE

COVERED INTERVAL

TRUE THICKNESS OF INTERVAL NOT REPRESENTED

ABBREVIATIONS

ss = sandstone
slts = siltstone
sh = shale
f = fine
m = medium
c = coarse
cgl = conglomerate
max = maximum
MDBM = Mount Diablo Baseline and Meridian

FACIES

(from Mutti and Ricci Lucchi, 1972, 1975)

A, B, C, D, E, F, G

BOUMA DIVISIONS

(from Bouma, 1962)

a, b, c, d, e

MISCELLANEOUS

1) The term "massive" is restricted to that defined by the Bouma T_a division.
2) Bed boundaries are not split across pages unless otherwise indicated.

SEDIMENTARY AND BIOGENIC STRUCTURES

m MASSIVE BEDDED

≡ PLANAR BEDDED

RIPPLE LAMINATED

CONVOLUTE LAMINATED

PLANAR CROSS-STRATIFIED

TROUGH CROSS-STRATIFIED

HUMMOCKY CROSS-STRATIFIED

ISOLATED CONCRETIONS

C CONCRETIONARY

SHALE RIP-UP CLASTS

e SHELL/SHELL FRAGMENTS

CARBONACEOUS MATERIAL

T_s SLIGHTLY BURROWED

T_i INTENSELY BURROWED

T_c COMPLETELY BURROWED

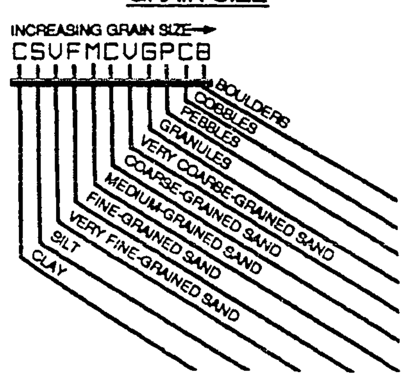
DEWATERING STRUCTURES

FLAME STRUCTURES

PINCH-AND-SWELL STRUCTURES

DEFORMED BED

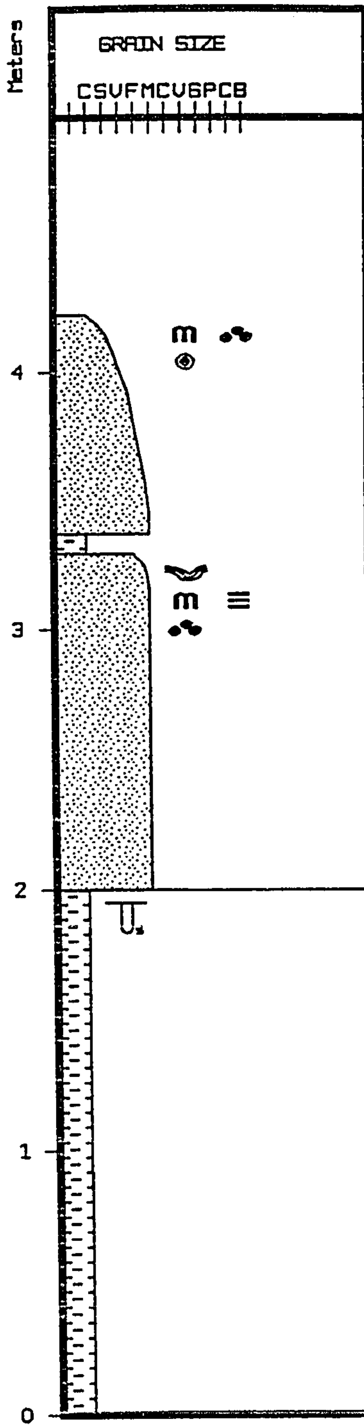
GRAIN SIZE



Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM

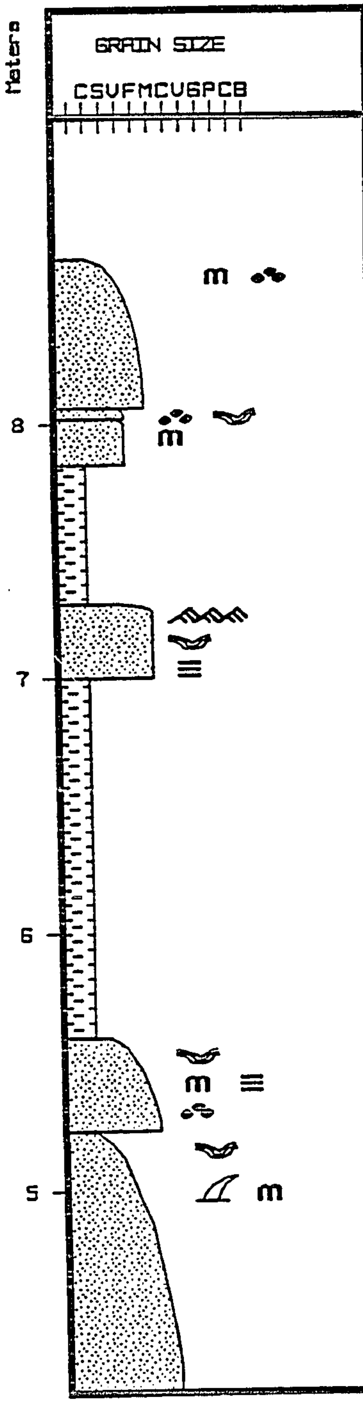
Tehama County, California



Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
Lobe 1	Ss, massive bedded, shale rip-up clasts, concretionary, scoured base, flute casts, 4 cm of downcutting	BG	ae	Guinda Formation
Lobe 1	Shale	G	e	Guinda Formation
Lobe 1	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	C	abc	Guinda Formation
Basin Plain	Shale, slightly burrowed, poorly exposed, base covered, total thickness not measured	G	e	Funks Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 2	Ss, massive bedded, shale rip-up clasts, scoured base, 8 cm of downcutting	BG	ae	Guinda Formation
Lobe 2	Ss, convolute laminated, shale rip-up clasts, poorly exposed	DG	bce	Guinda Formation
Lobe 2	Ss, massive bedded	B	a	Guinda Formation
Interlobe	Shale, poorly exposed	G	e	Guinda Formation
Interlobe	Ss, planar laminated, ripple laminated, convolute laminated	D	bc	Guinda Formation
Interlobe	Shale, poorly exposed	G	e	Guinda Formation
Lobe 1	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, ferruginous concretions	D	bc	Guinda Formation
Lobe 1	Ss, massive bedded, convolute laminated, flame structure	BG	ace	Guinda Formation

Black Butte Reservoir, South Shore

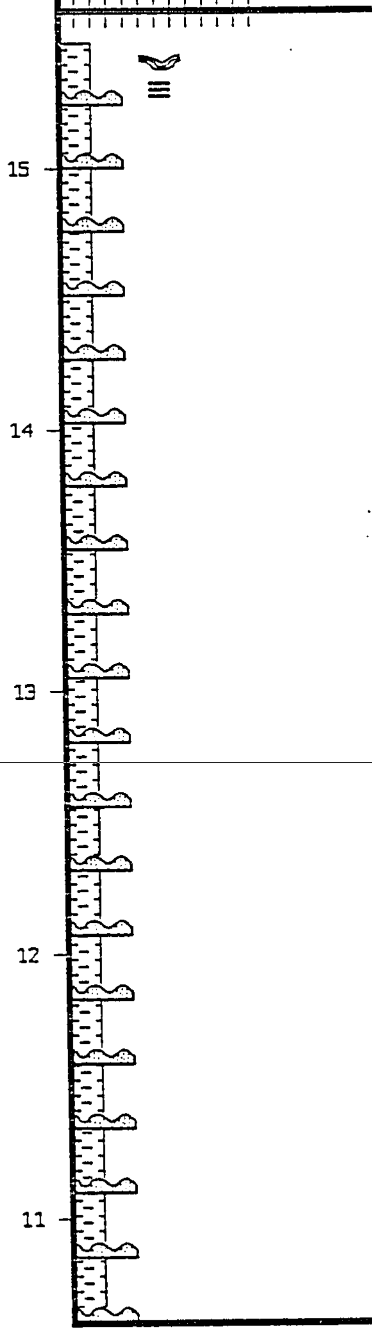
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interlobe	Ss, planar laminated, convolute laminated, pinch and swell, scoured base, 4 cm of downcutting	D	bc	Guinda Formation
Lobe 2	Ss, planar laminated, convolute laminated	DG	bce	
	Shale, carbonaceous material	G	e	
	Ss, planar laminated, convolute laminated	D	bc	
	Shale, carbonaceous material	G	e	
	Ss, planar laminated, convolute laminated	D	bc	
	Ss, massive bedded, planar laminated, convolute laminated	CG	abce	
	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, scoured base, 6 cm of downcutting	C	abc	

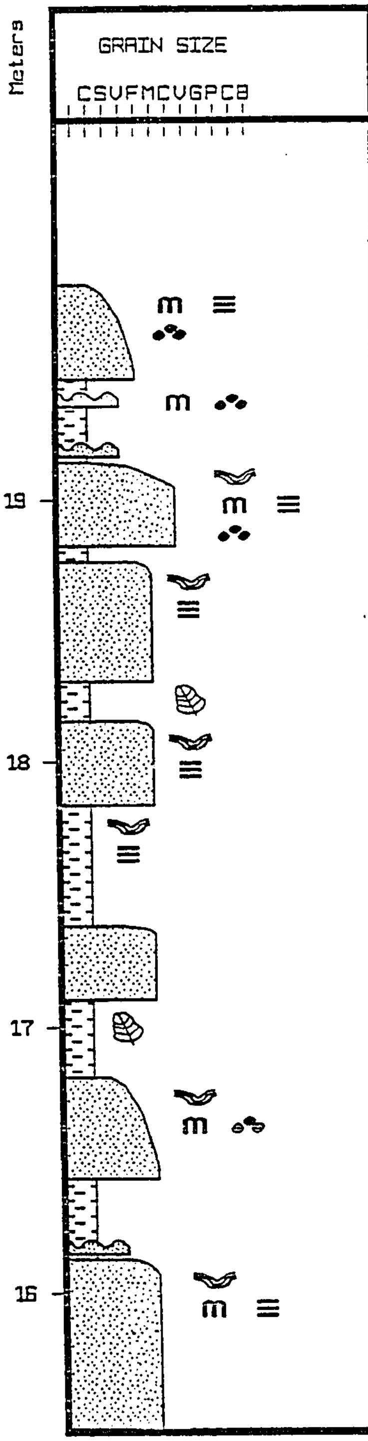
Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

Meters	GRAIN SIZE CSVFMCVGPCB	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
		Interlobe	Interbedded shale and ss (ss:sh = 1:3), planar laminated, convolute laminated, silty shale, max bed thickness=8 cm	DG	bce	Guinda Formation

Black Butte Reservoir, South Shore

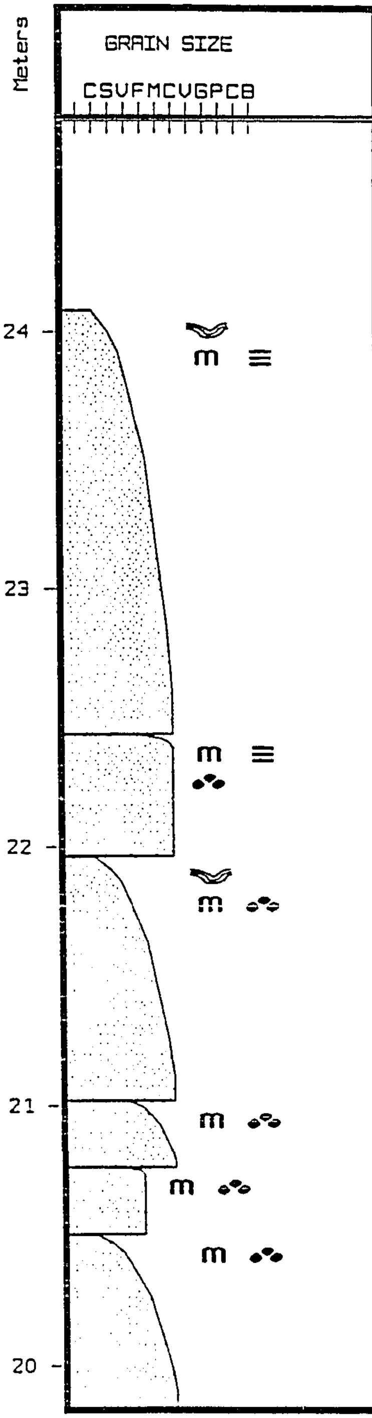
C SE Sec. 31 T.21N. R.4W. MDBM Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 4	Ss, massive bedded, planar laminated, shale rip-up clasts	CG	abce	Guinda Formation
Lobe 4	Interbedded shale and ss (ss:sh = 1:3), massive bedded, shale rip-up clasts, max bed thickness=6 cm	DG	bce	Guinda Formation
Lobe 3	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	D	bc	Guinda Formation
Lobe 3	Shale, carbonaceous material	G	e	Guinda Formation
Lobe 3	Ss, planar laminated, convolute laminated, scoured base, 6 cm of downcutting	D	bc	Guinda Formation
Lobe 3	Shale	G	e	Guinda Formation
Lobe 3	Ss, planar laminated, convolute laminated, scoured base, 4 cm of downcutting	D	bc	Guinda Formation
Lobe 3	Shale, planar laminated, convolute laminated, sample 89-DBS-02SH	G	e	Guinda Formation
Lobe 3	Ss, poorly exposed	?	?	Guinda Formation
Lobe 3	Shale, carbonaceous material	G	e	Guinda Formation
Lobe 3	Ss, massive bedded, convolute laminated, shale rip-up clasts	B	ac	Guinda Formation
Lobe 3	Interbedded shale and ss (ss:sh = 1:3), max bed thickness=7 cm	DG	bce	Guinda Formation
Lobe 3	Ss, massive bedded, planar laminated, convolute laminated, flute casts, sample 89-DBS-01SS	C	abc	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

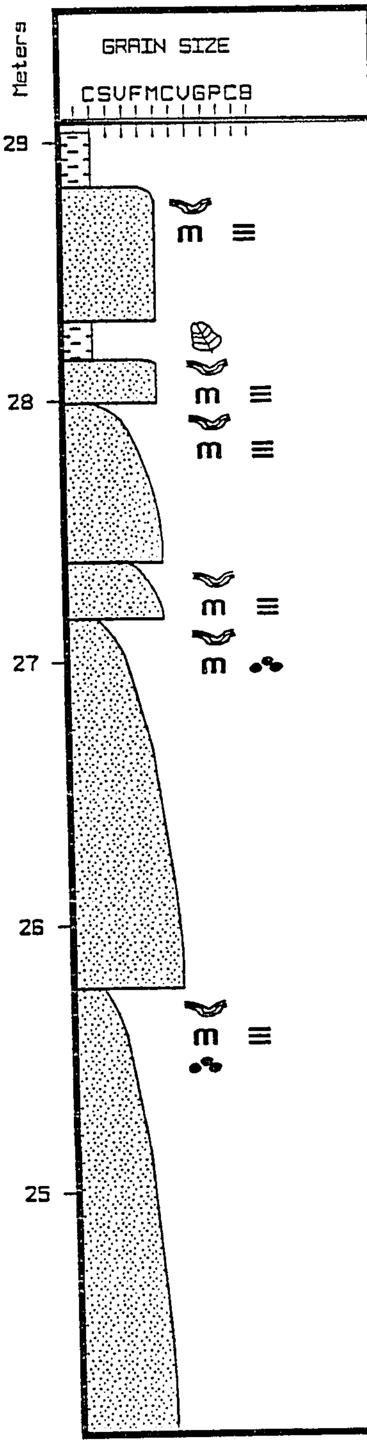


Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
24	Lobe 4	Ss, massive bedded, planar laminated, convolute laminated, scoured base, 12 cm of downcutting	CG	abce	Guinda Formation
22	Lobe 4	Ss, massive bedded, planar laminated, shale rip-up clasts	B	ab	Guinda Formation
22	Lobe 4	Ss, massive bedded, convolute laminated, shale rip-up clasts, scoured base, flute casts, 8 cm of downcutting	BG	ace	Guinda Formation
21	Lobe 4	Ss, massive bedded, shale rip-up clasts	B	a	Guinda Formation
	Lobe 4	Ss, massive bedded, shale rip-up clasts	B	a	Guinda Formation
20	Lobe 4	Ss, massive bedded, shale rip-up clasts	BG	ae	Guinda Formation

Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

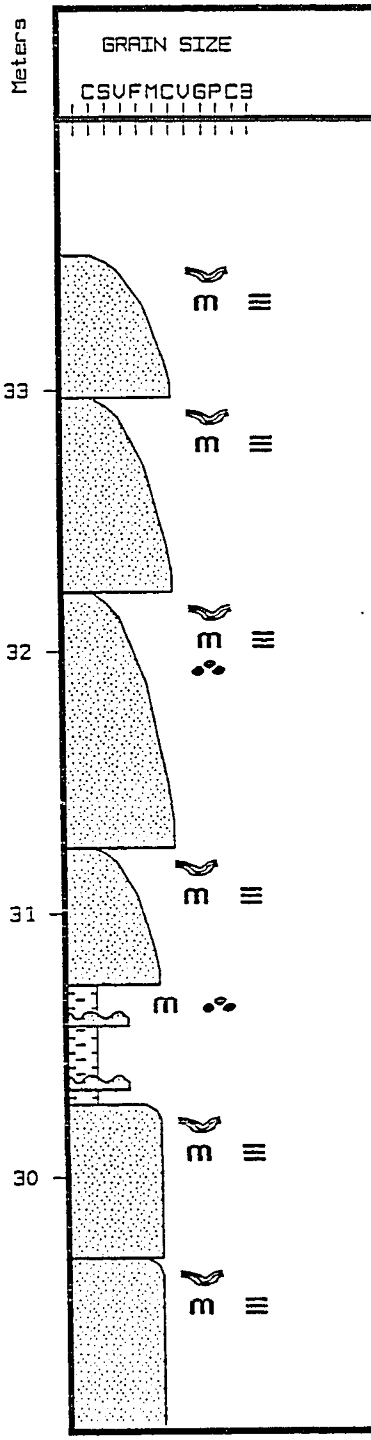


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 5	Shale	G	e	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated, poorly exposed	C	abc	Guinda Formation
Lobe 5	Shale, carbonaceous material	G	e	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated	CG	abce	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
Lobe 4	Ss, massive bedded, convolute laminated, shale rip-up clasts, scoured base, 8 cm of downcutting	BG	ace	Guinda Formation
Lobe 4	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	CG	abce	Guinda Formation

Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

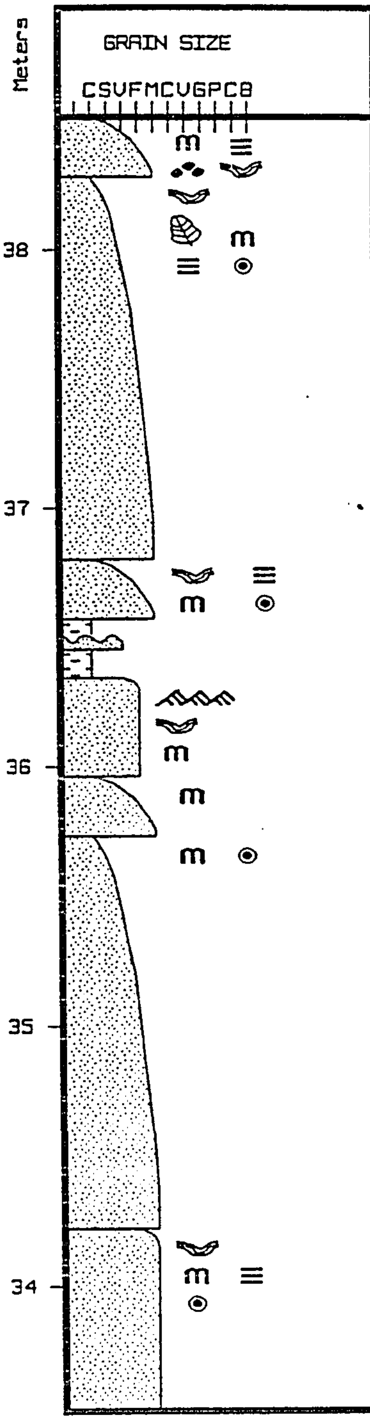


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 6				Guinda Formation
Lobe 6	Ss, massive bedded, planar laminated, convolute laminated	EG	ae	Guinda Formation
Lobe 6	Ss, massive bedded, planar laminated, convolute laminated	CG	abce	Guinda Formation
Lobe 6	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	CG	abce	Guinda Formation
Lobe 6	Ss, massive bedded, planar laminated, convolute laminated	CG	abce	Guinda Formation
Lobe 6	Interbedded shale and ss (ss:sh = 1:3), massive bedded, shale rip-up clasts, max bed thickness=6 cm, poorly exposed	DG	bce	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
Lobe 5	Ss, massive bedded, planar laminated, convolute laminated	D	bc	Guinda Formation

Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 7	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	C6	abce	Guinda Formation
Lobe 7	Ss, massive bedded, planar laminated, convolute laminated, concretionary carbonaceous material, scoured base, 12 cm of downcutting	C6	abce	Guinda Formation
Lobe 7	Ss, massive bedded, planar laminated, convolute laminated, concretionary	C6	abce	Guinda Formation
Lobe 7	Interbedded shale and ss (ss:sh = 1:3), max bed thickness=4 cm	D6	bce	Guinda Formation
Lobe 6	Ss, massive bedded, ripple laminated, convolute laminated, scoured base, 2 cm of downcutting	C	ac	Guinda Formation
Lobe 6	Ss, massive bedded, scoured base, 2 cm of downcutting	B6	ae	Guinda Formation
Lobe 6	Ss, massive bedded, concretionary	B6	ae	Guinda Formation
Lobe 6	Ss, massive bedded, planar laminated, convolute laminated, concretionary	C	abc	Guinda Formation

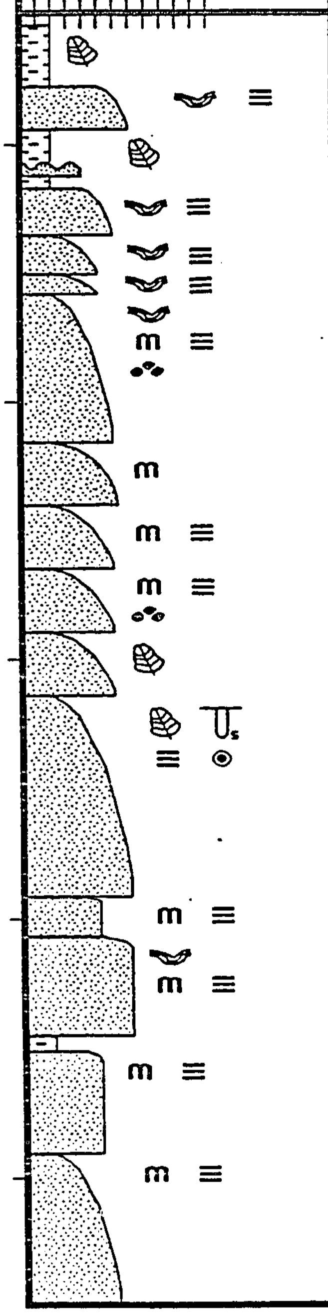
Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

GRAIN SIZE

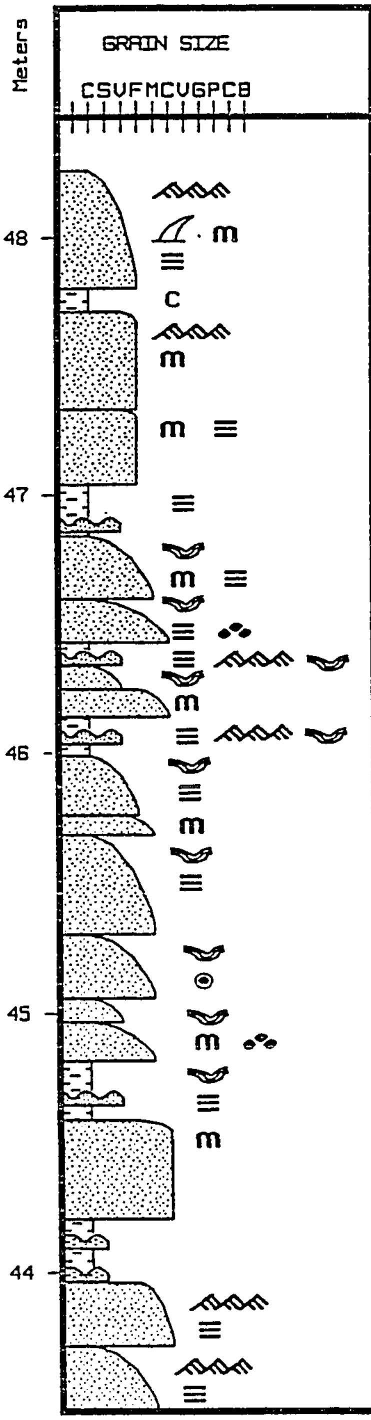
CSVFMCVGPCB



Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Lobe 8	Shale, carbonaceous material	G	e	Guinda Formation
	Lobe 8	Ss, planar laminated, convolute laminated	D	bc	Guinda Formation
43	Lobe 8	Interbedded shale and ss (ss:sh = 1:3), carbonaceous material, max bed thickness=5 cm	DG	bce	Guinda Formation
	Lobe 8	Ss, planar laminated, convolute laminated	D	bc	Guinda Formation
	Lobe 8	Ss, planar laminated, convolute laminated	DG	bce	Guinda Formation
	Lobe 8	Ss, planar laminated, convolute laminated	DG	bce	Guinda Formation
42	Lobe 7	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, scoured base, 8 cm of downcutting	CG	abce	Guinda Formation
	Lobe 7	Ss, massive bedded, laterally discontinuous	EG	ae	Guinda Formation
	Lobe 7	Ss, massive bedded, planar laminated, laterally discontinuous	EG	abe	Guinda Formation
	Lobe 7	Ss, massive bedded, planar laminated, shale rip-up clasts	EG	abe	Guinda Formation
41	Lobe 7	Ss, carbonaceous material	B	a	Guinda Formation
	Lobe 7	Ss, planar laminated, concretionary, carbonaceous material, slightly burrowed	BG	abe	Guinda Formation
40	Lobe 7	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
	Lobe 7	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
	Lobe 7	Shale	G	e	Guinda Formation
	Lobe 7	Ss, massive bedded, planar laminated	C	abc	Guinda Formation
39	Lobe 7	Ss, massive bedded, planar laminated, poorly exposed	BG	abe	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

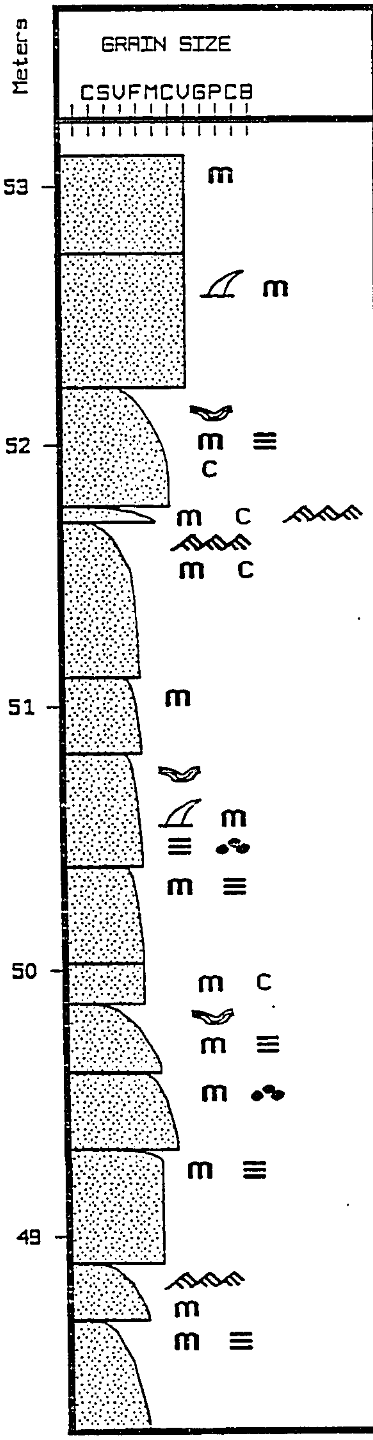
Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 10	Ss, massive bedded, planar laminated, ripple laminated, flame structure	CG	abce	Guinda Formation
Lobe 10	Shale, concretionary	G	e	Guinda Formation
Lobe 10	Ss, massive bedded, ripple laminated	C	abc	Guinda Formation
Lobe 10	Ss, massive bedded, planar laminated, scoured base, 2 cm of downcutting	B	ab	Guinda Formation
Lobe 10	Interbedded shale and ss (ss:sh = 1:3), planar laminated, max bed thickness= 4 cm	DG	bce	Guinda Formation
Lobe 10	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
Lobe 10	Ss, planar laminated, convolute laminated, shale rip-up clasts	CG	abce	Guinda Formation
Lobe 9	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, convolute laminated, max bed thickness= 4 cm	DG	bce	Guinda Formation
Lobe 9	Ss, convolute laminated	DG	ce	Guinda Formation
Lobe 9	Ss, massive bedded	B	a	Guinda Formation
Lobe 9	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, convolute laminated, max bed thickness= 6 cm	DG	ace	Guinda Formation
Lobe 9	Ss, planar laminated, convolute laminated	B	a	Guinda Formation
Lobe 9	Ss, massive bedded	DG	bce	Guinda Formation
Lobe 9	Ss, planar laminated, convolute laminated	DG	bce	Guinda Formation
Lobe 9	Ss, convolute laminated, concretionary	DG	ce	Guinda Formation
Lobe 9	Ss, convolute laminated	BG	ce	Guinda Formation
Lobe 9	Ss, massive bedded, shale rip-up clasts	BG	ae	Guinda Formation
Lobe 9	Interbedded ss and shale (ss:sh = 1:1), planar laminated, convolute laminated, max bed thickness=6 cm	DG	bce	Guinda Formation
Lobe 8	Ss, massive bedded, poorly exposed	D	bc	Guinda Formation
Lobe 8	Interbedded shale and slts (slts:sh = 1:3), max bed thickness=4 cm	G	e	Guinda Formation
Lobe 8	Ss, planar laminated, ripple laminated	D	bc	Guinda Formation
Lobe 8	Ss, planar laminated, ripple laminated	DG	bce	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 1	Ss, massive bedded	B	a	Guinda Formation
Channel 1	Ss, massive bedded, flame structure	B	a	Guinda Formation
Lobe 11	Ss, massive bedded, planar laminated, convolute laminated, concretionary, scoured base, 8 cm of downcutting	B	abc	Guinda Formation
Lobe 11	Ss, massive bedded, ripple laminated, concretionary, laterally discontinuous	BG	ace	Guinda Formation
Lobe 11	Ss, massive bedded, ripple laminated, concretionary, laterally discontinuous	CG	abce	Guinda Formation
Lobe 11	Ss, massive bedded	B	a	Guinda Formation
Lobe 11	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, flame structure	B	abc	Guinda Formation
Lobe 11	Ss, massive bedded, planar laminated, scoured base, 6 cm of downcutting	B	ab	Guinda Formation
Lobe 11	Ss, massive bedded, concretionary	B	a	Guinda Formation
Lobe 10	Ss, massive bedded, planar laminated, convolute laminated, scoured base, 8 cm of downcutting	BG	abce	Guinda Formation
Lobe 10	Ss, massive bedded, shale rip-up clasts, scoured base, 4 cm of downcutting	B	a	Guinda Formation
Lobe 10	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Lobe 10	Ss, massive bedded, ripple laminated, irregular base	CG	abce	Guinda Formation
Lobe 10	Ss, massive bedded, planar laminated, scoured base	BG	ae	Guinda Formation

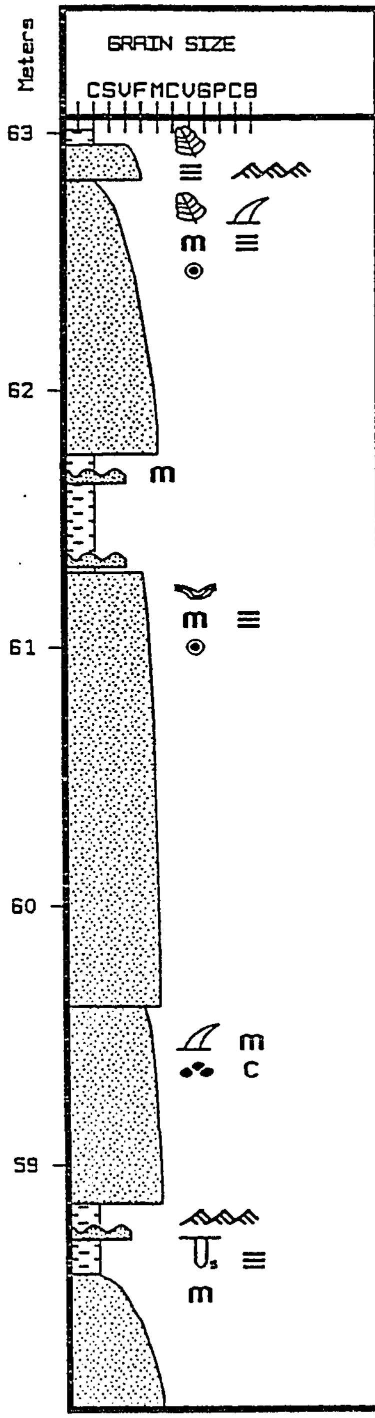
Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

Meters	GRAIN SIZE (C S VF F M C VC G P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
58	m c	Channel 2	Ss, massive bedded, concretionary	B	a	Guinda Formation
	m	Channel 2	Ss, massive bedded	B	a	Guinda Formation
57	m	Channel 2	Ss, massive bedded	B	a	Guinda Formation
	m	Channel 2	Ss, massive bedded, concretionary	B	a	Guinda Formation
	m	Channel 2	Ss, massive bedded	B	a	Guinda Formation
56	m	Channel 2	Ss, massive bedded	B	a	Guinda Formation
	m	Channel 2	Ss, massive bedded, concretionary	B	a	Guinda Formation
	m	Channel 2	Ss, massive bedded, shale rip-up clasts, concretionary	B	a	Guinda Formation
55	m	Channel 2	Ss, massive bedded, shale rip-up clasts, concretionary	B	a	Guinda Formation
	m	Channel 1	Ss, massive bedded, flame structure	B	a	Guinda Formation
54	m	Channel 1	Ss, massive bedded	B	a	Guinda Formation
	m	Channel 1	Ss, massive bedded	B	a	Guinda Formation
	m	Channel 1	Ss, massive bedded, flame structure	B	a	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 4	Shale, carbonaceous material	6	e	Guinda Formation
Channel 4	Ss, planar laminated, ripple laminated	D	bc	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated, concretionary, carbonaceous material, flame structure	BG	de	Guinda Formation
Channel 3	Interbedded shale and ss (ss:sh = 1:5), massive bedded, max bed thickness=8 cm	BE 6	ae	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, convolute laminated, concretionary	B	abc	Guinda Formation
Channel 3	Ss, massive bedded, shale rip-up clasts, concretionary, flame structure	B	a	Guinda Formation
Channel 2	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, slightly burrowed, max bed thickness=4 cm	DE 6	bce	Guinda Formation
Channel 2	Ss, massive bedded	BG	ae	Guinda Formation

Black Butte Reservoir, South Shore

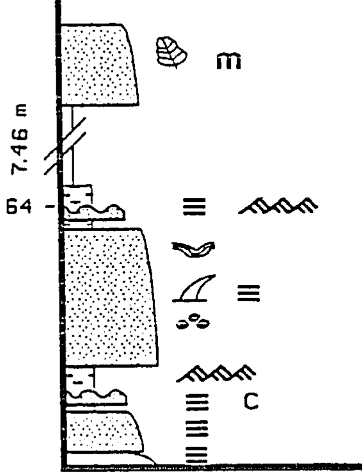
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California

Meters

GRAIN SIZE

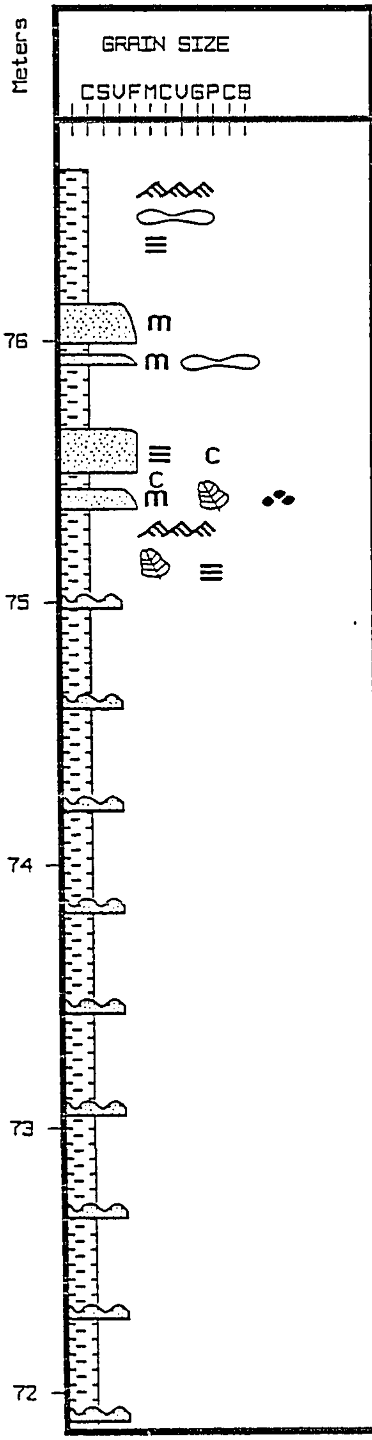
CSVFMCVGPCB



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Ss, massive bedded, carbonaceous material, poorly exposed	B	a	Guinda Formation
Interchannel	Covered interval, shale at top	?	?	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, max bed thickness=4 cm	DE G	bce	Guinda Formation
Channel 5	Ss, planar laminated, convolute laminated, shale rip-up clasts, flame structure	B	bc	Guinda Formation
Channel 5	Interbedded ss and shale (ss:sh = 1:1), planar laminated, ripple laminated, concretionary, max bed thickness=6 cm	DE G	bce	Guinda Formation
Channel 4	Ss, planar laminated, poorly exposed	E	ab	Guinda Formation
Channel 4	Ss, planar laminated, poorly exposed	E	ab	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

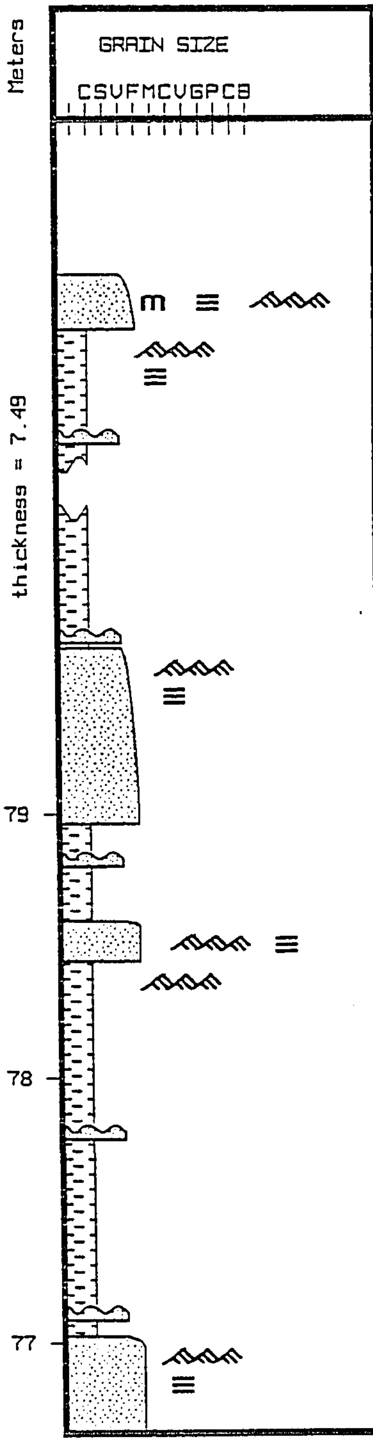
Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:9), planar laminated, ripple laminated, pinch and swell, max bed thickness=2 cm	DE G	bce	Guinda Formation
	Ss, massive bedded	B	a	
	Shale	G	e	
	Ss, massive bedded, pinch and swell	E	c	
	Shale, sample 89-DBS-035H	G	e	
	Ss, planar laminated, concretionary	E	c	
	Shale, concretionary	G	e	
	Ss, massive bedded, shale rip-up clasts, carbonaceous material/charcoal, poorly exposed	B	a	
	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, carbonaceous material, max bed thickness=6 cm	DE G	bce	

Black Butte Reservoir, South Shore

C SE Sec. 31 T.21N. R.4W. MDBM — Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Ss, massive bedded, planar laminated, ripple laminated	C	abc	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, max bed thickness=10 cm	DE G	bce	Guinda Formation
Crevasse Splay 1	Ss, planar laminated, ripple laminated, sample 89-DBS-045S	D	bc	
Interchannel	Interbedded shale and ss (ss:sh = 1:9), max bed thickness=6 cm	DE G	bce	
Interchannel	Ss, planar laminated, ripple laminated	D	bc	
Interchannel	Interbedded shale and ss (ss:sh = 1:7), ripple laminated, max bed thickness=2 cm	DE G	bce	
Interchannel	Ss, planar laminated, ripple laminated	D	bc	

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

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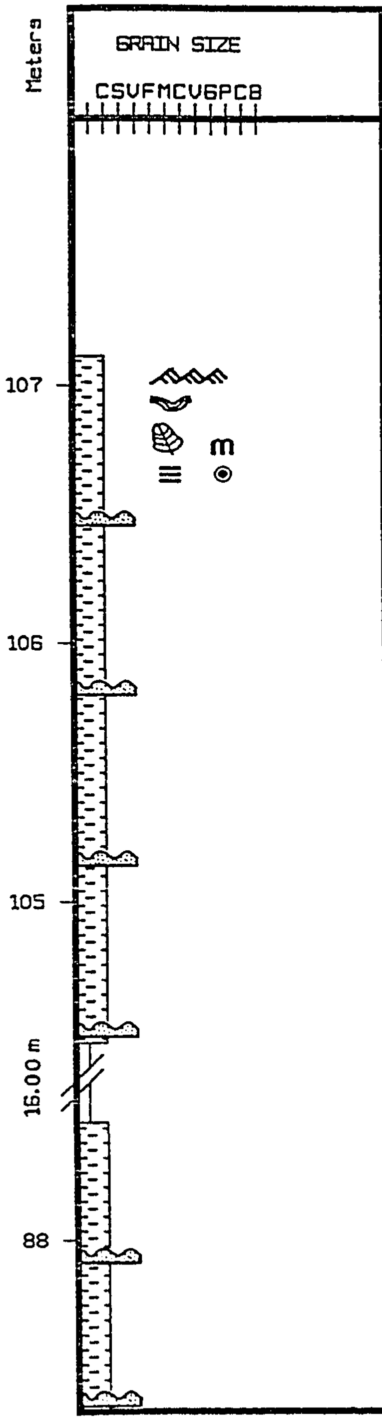
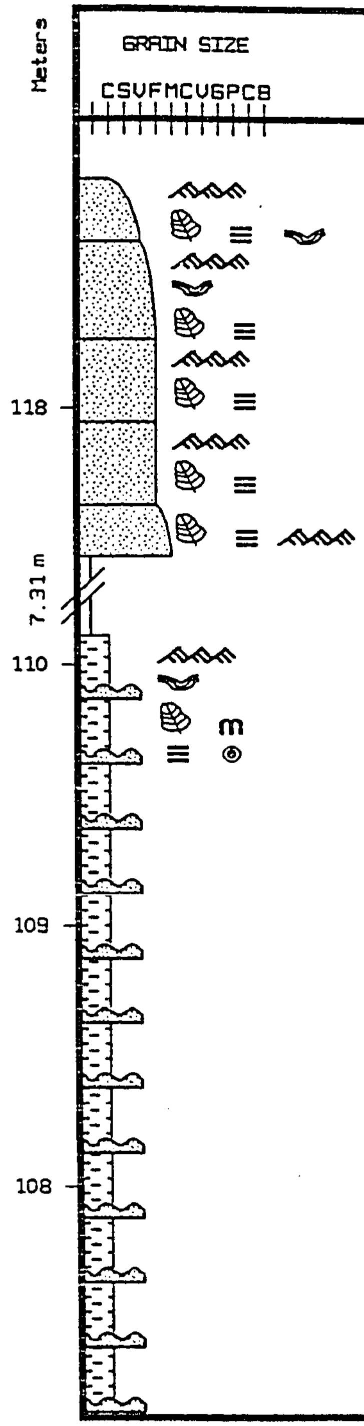
Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:9), massive bedded, planar laminated, ripple laminated, convolute laminated, concretionary, carbonaceous material, max bed thickness=6 cm	DE G	abce	Guinda Formation
	Covered interval, shale at top	?	?	
	Interbedded shale and ss (ss:sh = 1:7), max bed thickness=8 cm, poorly exposed	DE G	bce	

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

Tehama County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Crevasse Splay 2	Ss, planar laminated, ripple laminated, convolute laminated, carbonaceous material	D	bc	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, ripple laminated, convolute laminated, carbonaceous material	D	bc	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, ripple laminated, carbonaceous material	D	bc	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, ripple laminated, carbonaceous material	D	bc	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, ripple laminated, carbonaceous material	D	bc	Guinda Formation
Interchannel	Covered interval, shale at top	?	?	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:3), massive bedded, planar laminated, ripple laminated, convolute laminated, concretionary, carbonaceous material, max bed thickness=6 cm	DE G	abce	Guinda Formation

Black Butte Reservoir, South Shore
C SE Sec. 31 T.21N. R.4W. MDBM

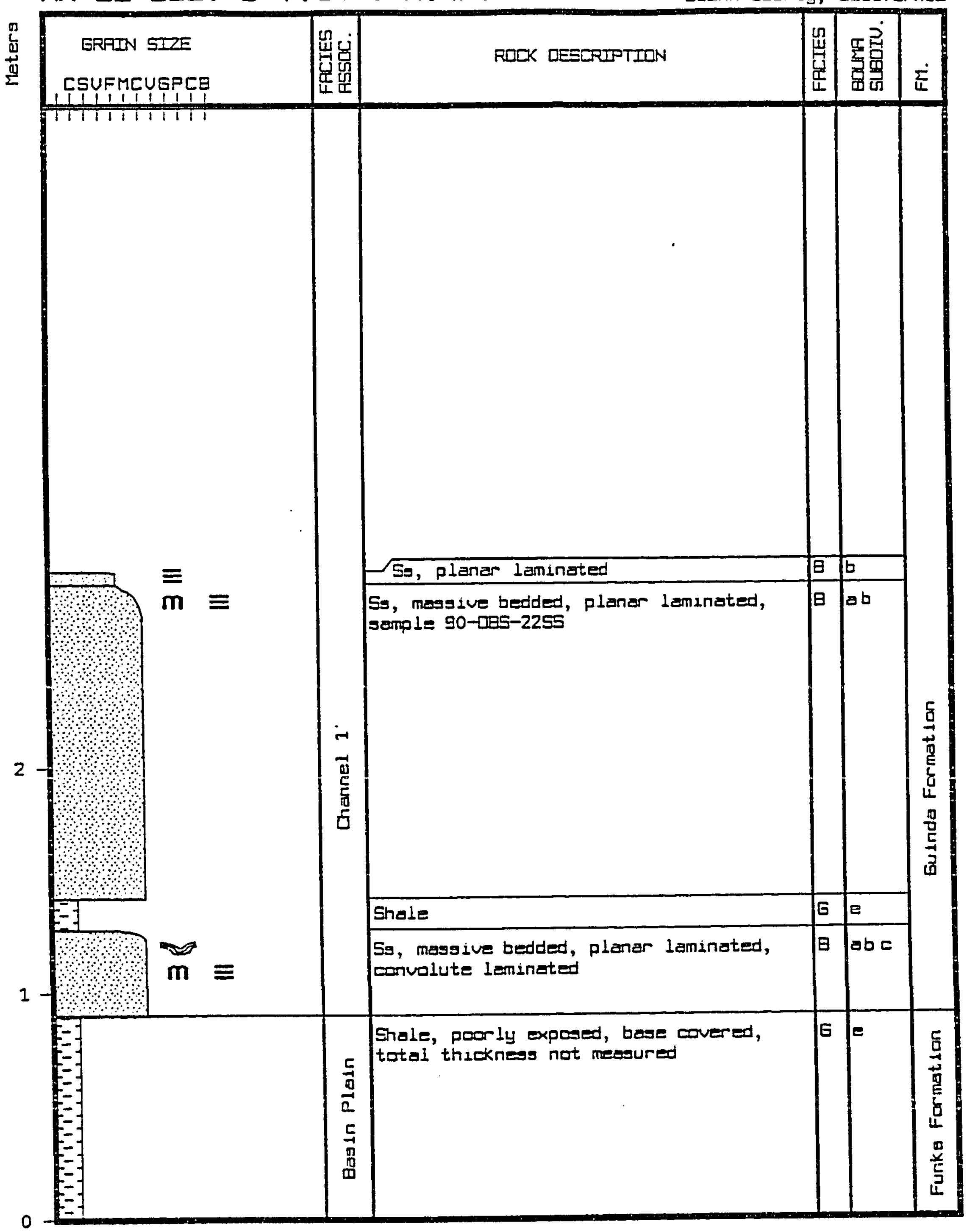
Tehama County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
119–120		Basin Plain	Shale, poorly exposed, total thickness not measured, sample 90-DBS-24SH retrieved 630 cm above last bed	G	e	Dobbins Shale Member

South Fork Willow Creek

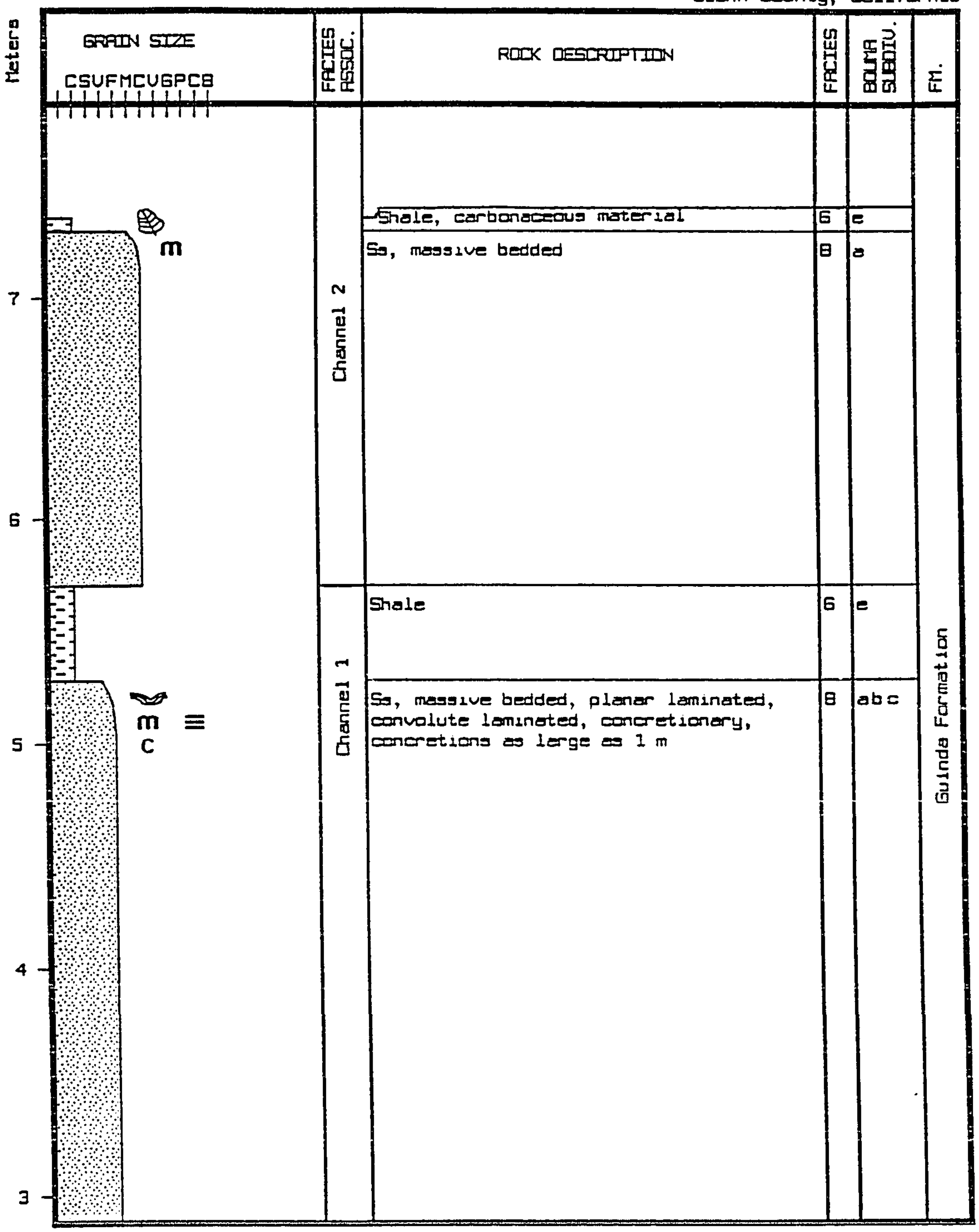
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California



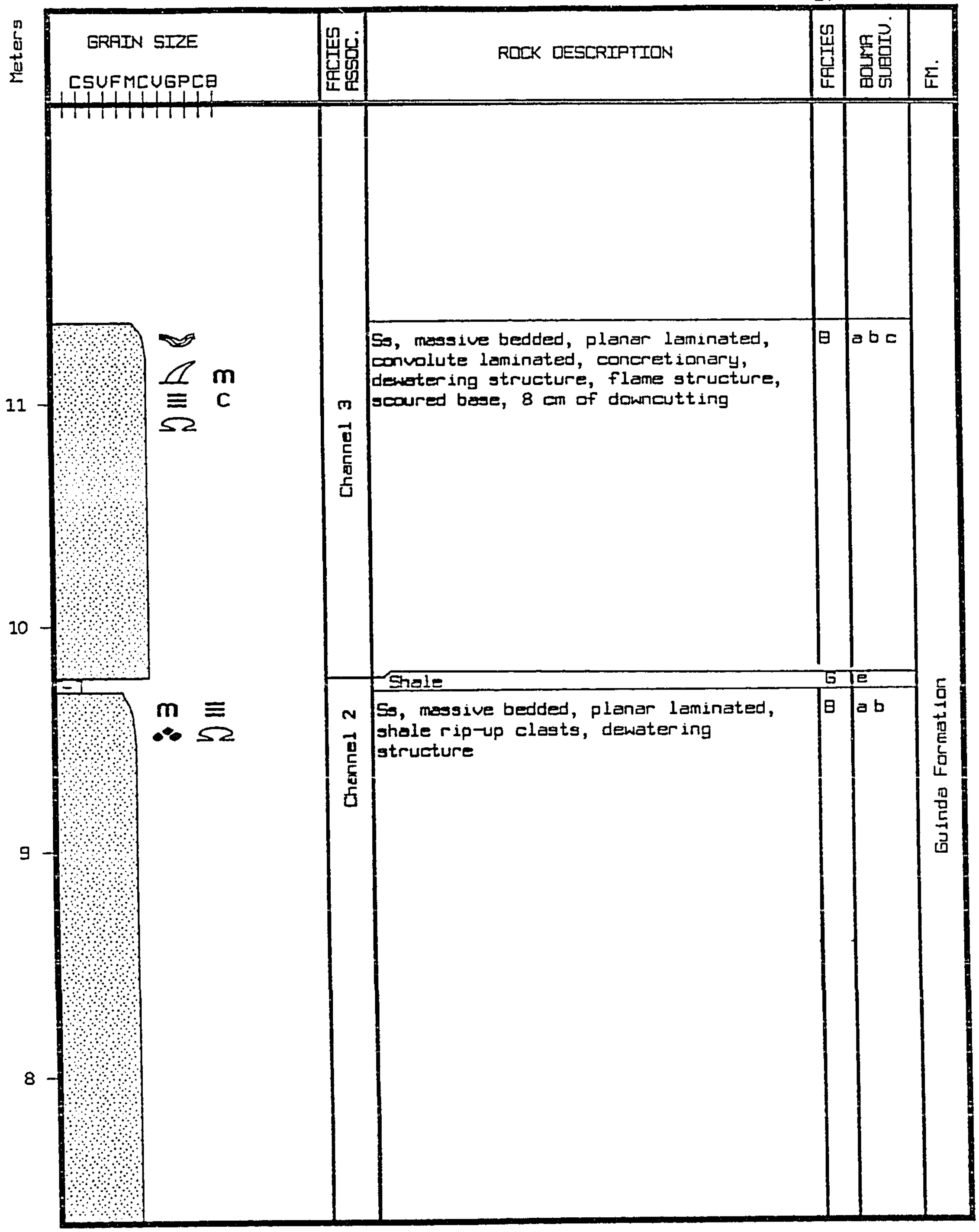
South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California



South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

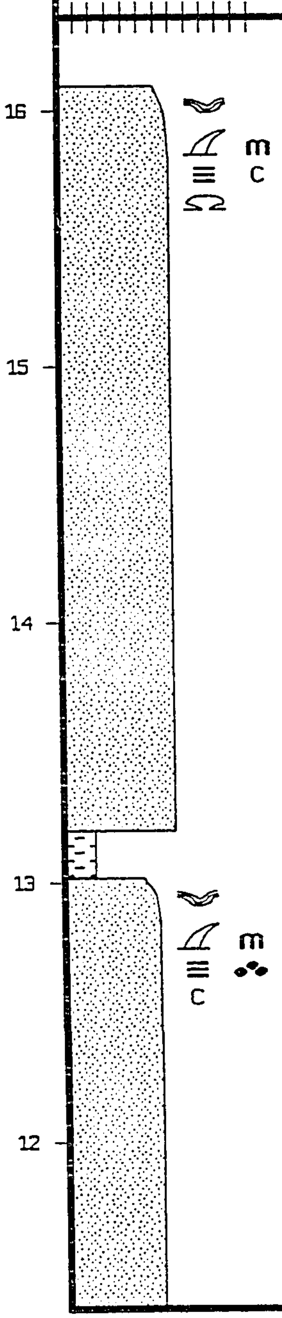


South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

GRAIN SIZE

CSVFMCVGPCB

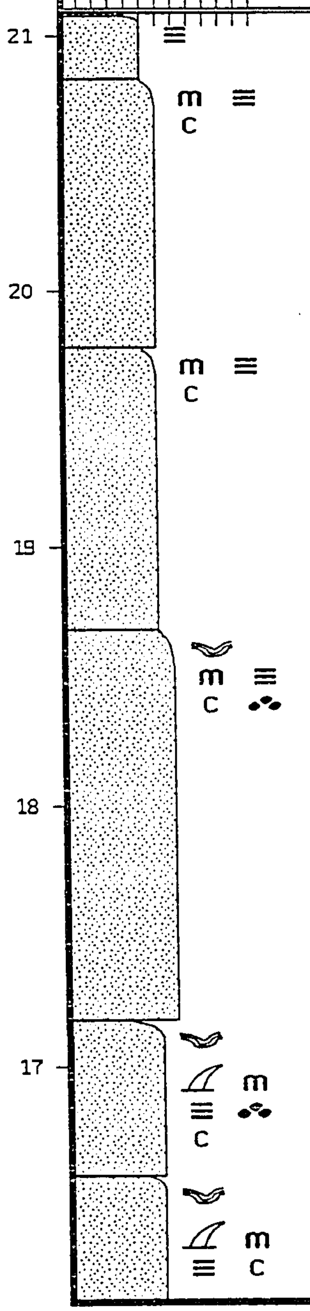


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 4	Ss, massive bedded, planar laminated, convolute laminated, concretionary, dewatering structure, flame structure	B	abc	Guinda Formation
Channel 3	Shale	G	e	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, concretionary, flame structure, isolated shale rip-up clasts at top	B	abc	Guinda Formation

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

Meters — GRAIN SIZE: C S VF M C VG P C B

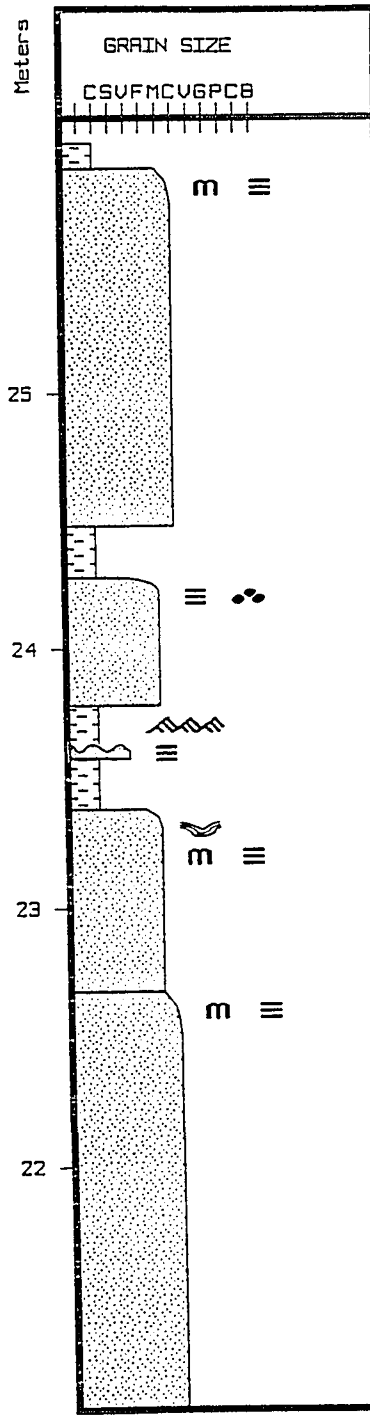


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 5	Ss, planar laminated	BD	b	Guinda Formation
Channel 5	Ss, massive bedded, planar laminated, concretionary	B	ab	Guinda Formation
Channel 5	Ss, massive bedded, planar laminated, concretionary	B	ab	Guinda Formation
Channel 5	Ss, massive bedded, planar laminated, convolute laminated, concretionary, pebbles and shale rip-up clasts at base	AB	abc	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, concretionary, flame structure	B	abc	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated, convolute laminated, concretionary, flame structure	B	abc	Guinda Formation

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

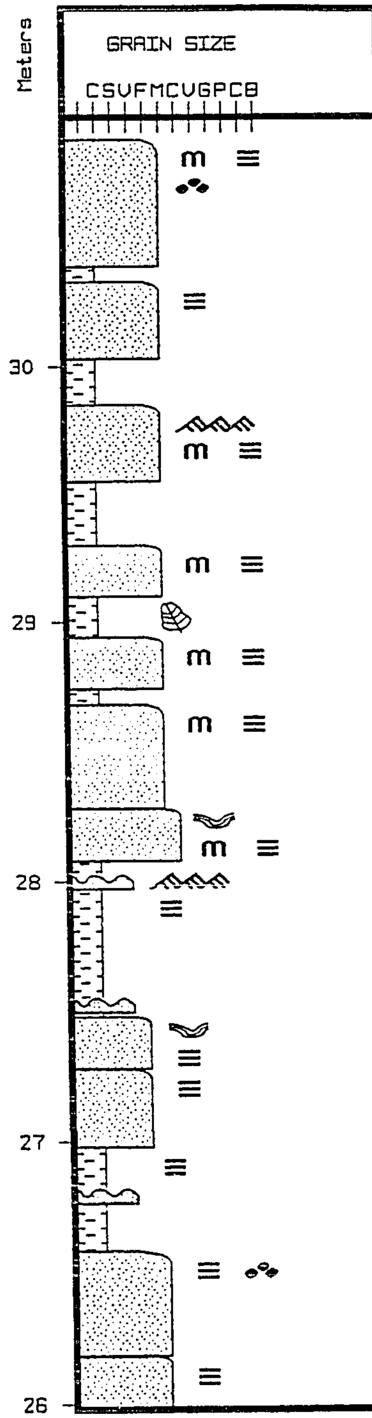


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 7	Shale	G	e	Guinda Formation
Channel 7	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 6	Shale	G	e	Guinda Formation
Channel 6	Ss, planar laminated, shale rip-up clasts, scoured base, 10 cm of downcutting	BG	be	Guinda Formation
Channel 6	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation
Channel 6	Ss, massive bedded, planar laminated, convolute laminated	B	abc	Guinda Formation
Channel 6	Ss, massive bedded, planar laminated	B	ab	Guinda Formation

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

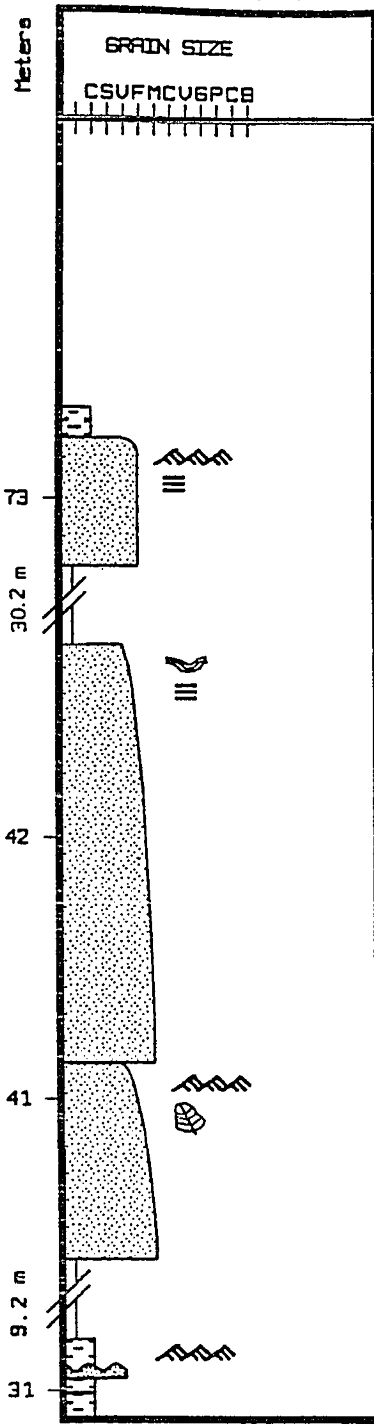
Glenn County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 8	Ss, massive bedded, planar laminated, shale rip-up clasts	B	ab	Guinda Formation
	Shale	G	e	
	Ss, planar laminated	B	b	
	Shale, poorly exposed	G	e	
	Ss, massive bedded, planar laminated, ripple laminated	B	abc	
	Shale	G	b	
	Ss, massive bedded, planar laminated	B	ab	
	Shale, carbonaceous material	G	b	
	Ss, massive bedded, planar laminated	B	ab	
	Shale	G	e	
	Ss, massive bedded, planar laminated	B	ab	
	Ss, massive bedded, planar laminated, convolute laminated	B	abc	
Channel 7	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=8 cm	DE G	bce	
	Ss, planar laminated, convolute laminated	D	bc	
	Ss, planar laminated, poorly exposed, shale at top	DG	be	
	Interbedded shale and ss (ss:sh = 1:7), planar laminated, max bed thickness=6 cm	DE G	bce	
	Ss, planar laminated, shale rip-up clasts	DG	be	
	Ss, planar laminated	DG	be	

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Shale, poorly exposed	6	e	Guinda Formation
Crevasse Splay 1	Ss, planar laminated, ripple laminated, poorly exposed	DE 6	bcde	
Inter-channel	Covered interval, scattered sandstone float	?	?	
Channel 9	Ss, planar laminated, convolute laminated	D	bc	
	Ss, ripple laminated, carbonaceous material	DE 6	ce	
Inter-channel	Covered interval, shale at top, scattered sandstone float	?	?	
	Interbedded shale and ss (ss:sh = 1:7), ripple laminated, max bed thickness=6 cm	DE 6	cde	
[illegible]	Shale	6	e	

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

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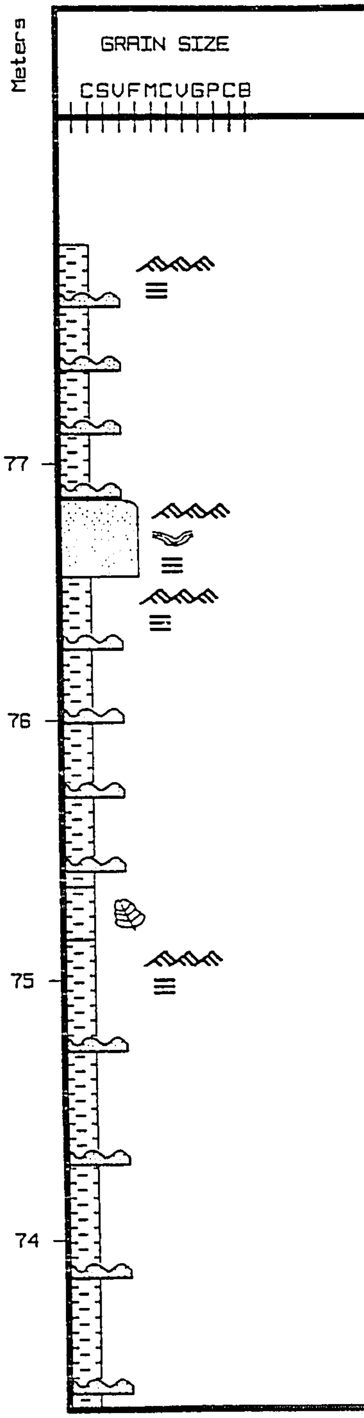
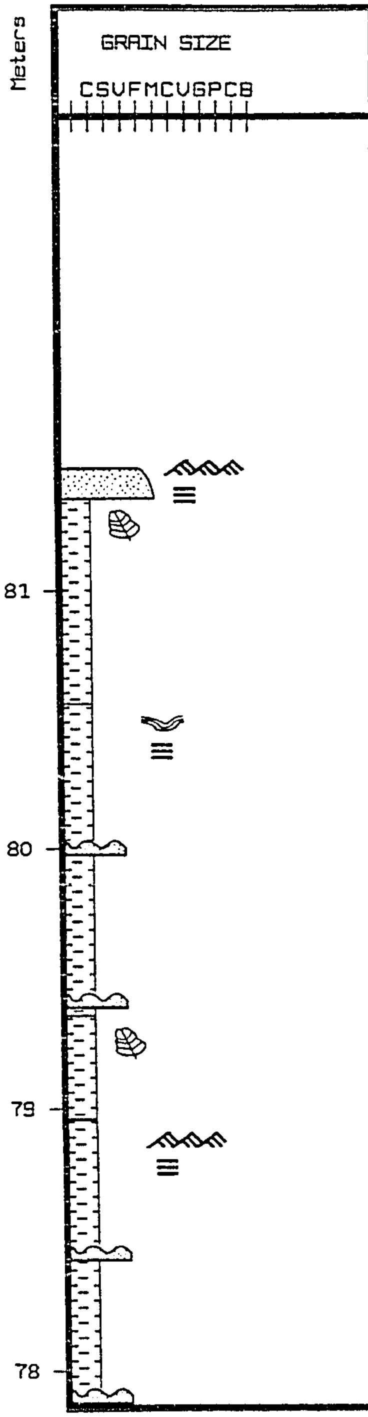


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bcde	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, ripple laminated, convolute laminated	D	bc	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bcd	Guinda Formation
Interchannel	Shale, carbonaceous material	G	b	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, poorly exposed, max bed thickness=6 cm	DE G	bcd	Guinda Formation

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

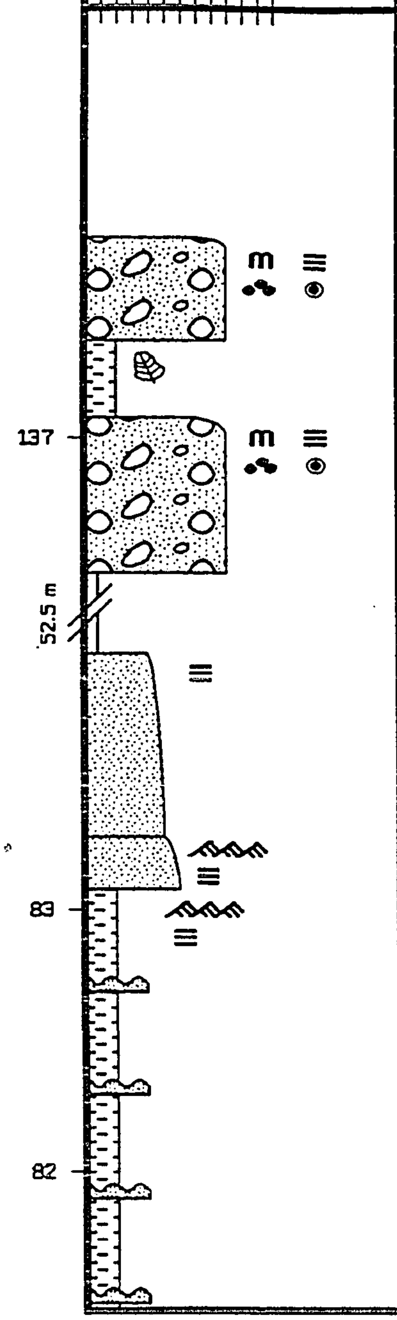


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Ss, planar laminated, ripple laminated, poorly exposed	D	bc	Guinda Formation
	Shale, carbonaceous material	G	e	
	Interbedded shale and ss (ss:sh = 1:7), planar laminated, convolute laminated, poorly exposed, max bed thickness=6 cm	CG	bce	
	Shale, carbonaceous material	G	e	
	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=8 cm	DE G	bcde	

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

Meters | GRAIN SIZE CSVFMCVGPCB



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 10	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses, scoured base, 10 cm of downcutting	A	ab	Guinda Formation
	Shale, carbonaceous material	G	e	
	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, ferruginous dolomite concretions, sandstone lens, scoured base, 8 cm of downcutting	A	ab	
Inter-chan-nel	Covered interval, shale at top, sandstone float	?	?	
Crevasse Splay 3	Ss, planar laminated, poorly exposed	DE G	bcd	
	Ss, planar laminated, ripple laminated, poorly exposed	D	b	
Interchannel	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, poorly exposed, shale at top, max bed thickness=8 cm	DE G	bce	

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

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Meters	GRAIN SIZE C S VF F M C VC G P C B	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
		Interchannel	Shale, poorly exposed	G	e	Guinda Formation

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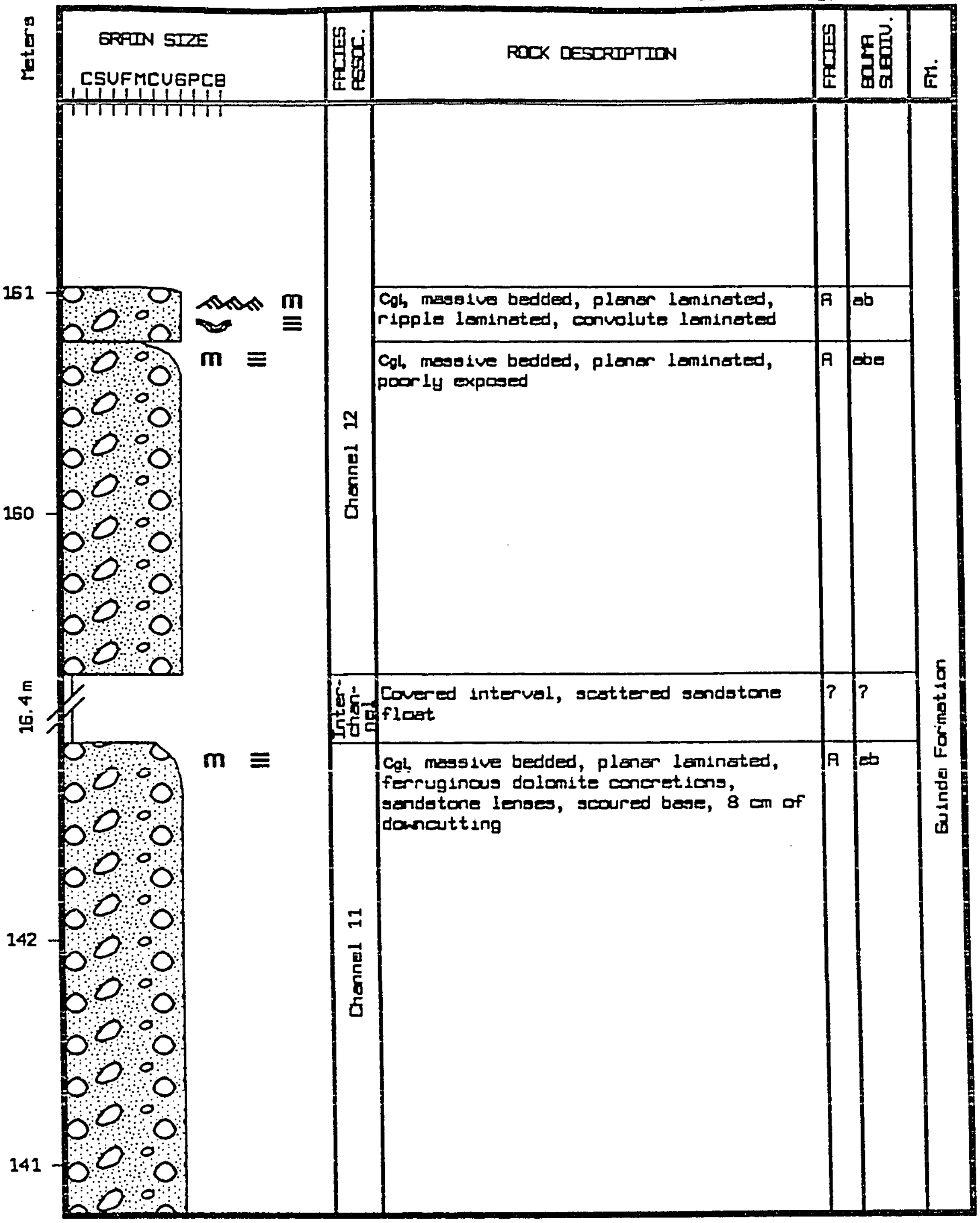
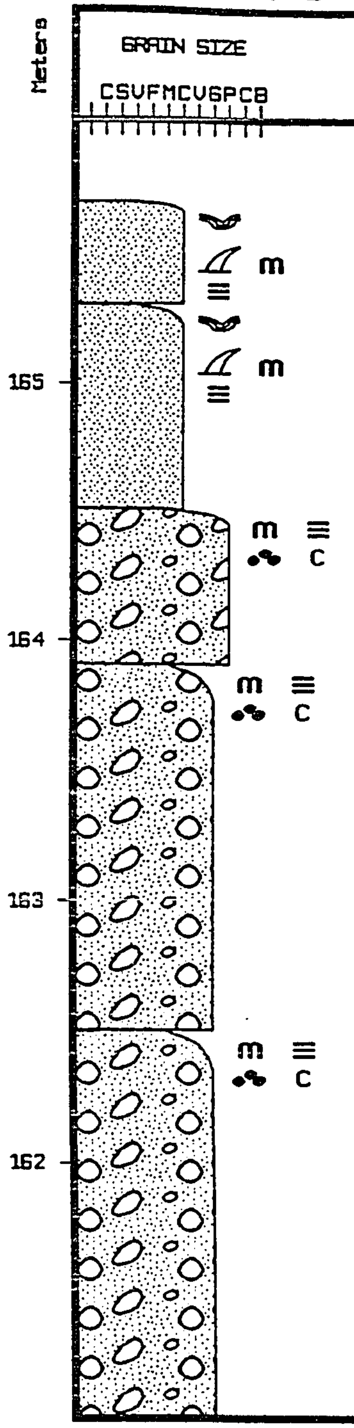
Glenn County, California



South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

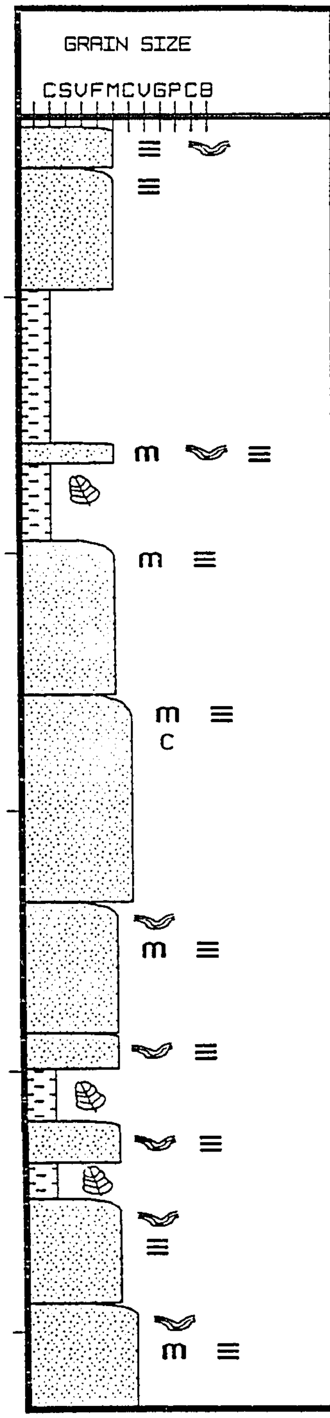


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 13	Sa, massive bedded, planar laminated, convolute laminated, flame structure	B	abc	Guinda Formation
Channel 13	Sa, massive bedded, planar laminated, convolute laminated, flame structure	A	abc	Guinda Formation
Channel 13	Clg, massive bedded, planar laminated, shale rip-up clasts, concretionary, pebbles at base, scoured base, 10 cm of downcutting	A	abc	Guinda Formation
Channel 12	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses	A	ab	Guinda Formation
Channel 12	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses	A	ab	Guinda Formation

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

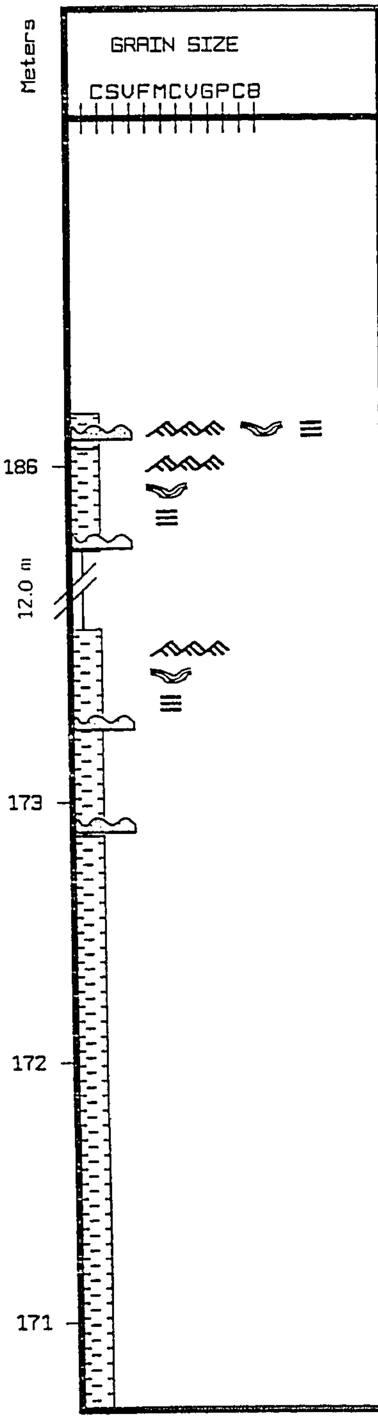
Glenn County, California



Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Crevasse Splay 4	Ss, planar laminated, convolute laminated	8D	bc	Guinda Formation
	Crevasse Splay 4	Ss, planar laminated, shale at top	8D	be	Guinda Formation
170	Channel 14	Shale, thin lenses of sandstone	6	e	Guinda Formation
	Channel 14	Ss, massive bedded, planar laminated, convolute laminated, shale at top	8	abce	Guinda Formation
	Channel 14	Shale, carbonaceous material	6	e	Guinda Formation
169	Channel 14	Ss, massive bedded, planar laminated	8	ab	Guinda Formation
168	Channel 14	Ss, massive bedded, planar laminated, concretionary, scoured base, 8 cm of downcutting, sample 90-DBS-265S	8	ab	Guinda Formation
	Channel 13	Ss, massive bedded, planar laminated, convolute laminated, shale at top	8	abce	Guinda Formation
167	Channel 13	Ss, planar laminated, convolute laminated	8	bc	Guinda Formation
	Channel 13	Shale, carbonaceous material	6	e	Guinda Formation
	Channel 13	Ss, planar laminated, convolute laminated	8	bc	Guinda Formation
	Channel 13	Shale, carbonaceous material	6	e	Guinda Formation
	Channel 13	Ss, planar laminated, convolute laminated	8	bc	Guinda Formation
166	Channel 13	Ss, massive bedded, planar laminated, convolute laminated, shale at top	8	abce	Guinda Formation

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

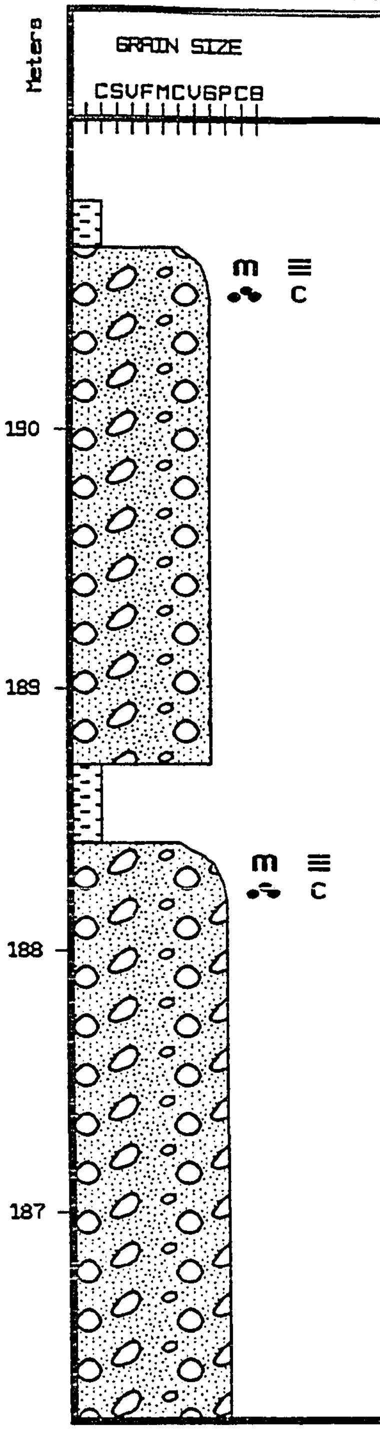
Glenn County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, convolute laminated, max bed thickness=4 cm	DE G	bce	Guinda Formation
	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, convolute laminated, max bed thickness=6 cm	DE G	bce	
	Covered interval, scattered sandstone float	?	?	
	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, convolute laminated, max bed thickness=10 cm	DE G	bce	
	Shale, poorly exposed	G	e	

South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

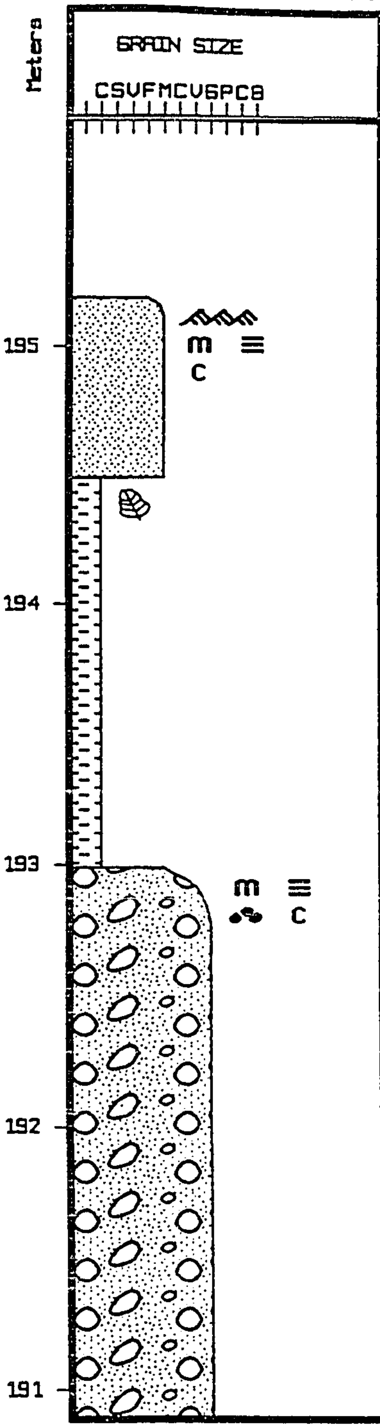


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 15	Shale	G	e	Guinda Formation
Channel 15	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses, scoured base, 10 cm of downcutting	A	ab	Guinda Formation
Channel 15	Shale	G	e	Guinda Formation
Channel 15	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses, scoured base, 8 cm of downcutting	A	ab	Guinda Formation

South Fork Willow Creek

NW SE Sec. 9 T.19N. R.4W. MDBM

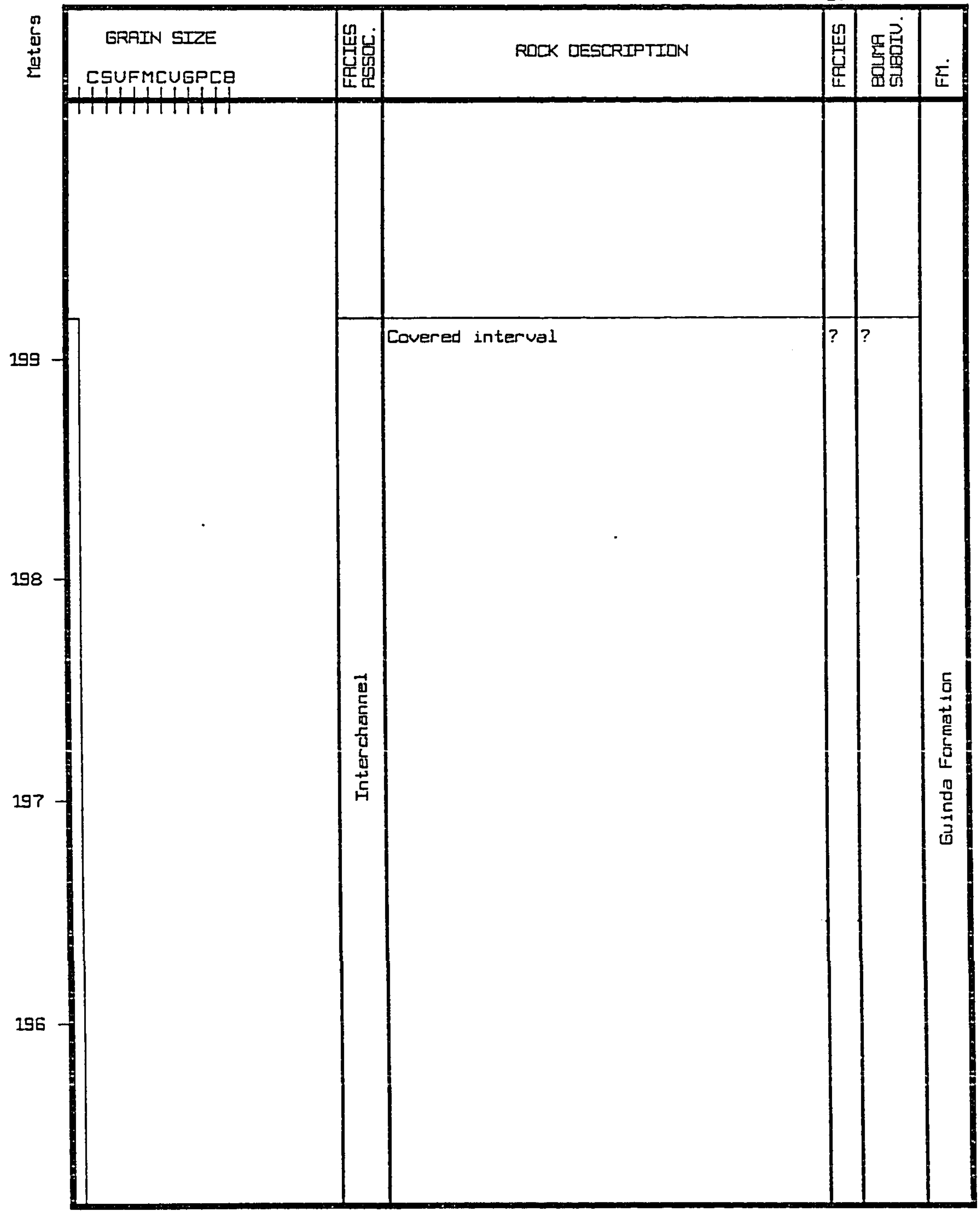
Glenn County, California



Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
Channel 15	Sa, massive bedded, planar laminated, ripple laminated, concretionary	BD	bc	Guinda Formation
Channel 15	Shale, carbonaceous material	G	e	Guinda Formation
Channel 15	Cgl, massive bedded, planar laminated, shale rip-up clasts, concretionary, sandstone lenses, scoured base, 10 cm of downcutting	A	ab	Guinda Formation

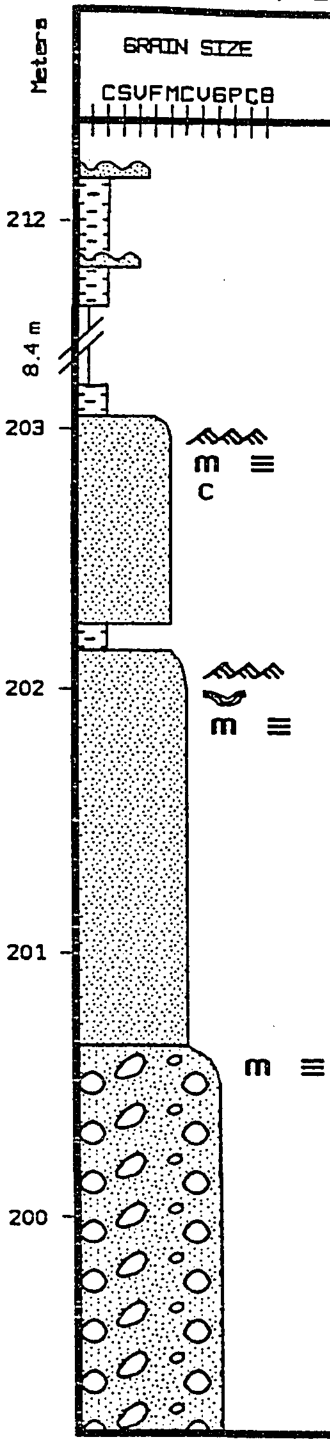
South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California



South Fork Willow Creek
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California

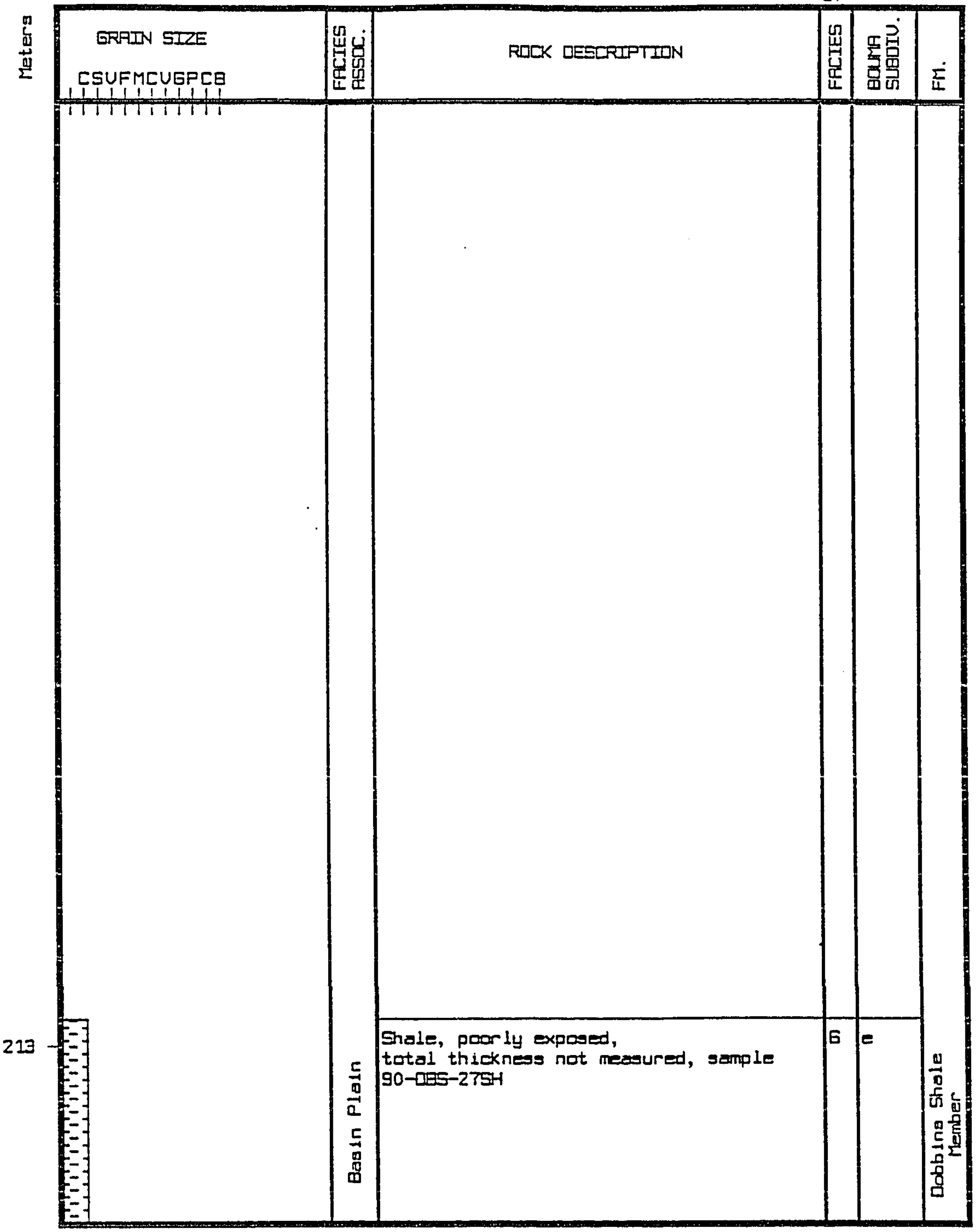


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:3), max bed thickness=15cm	DE G	bce	Guinda Formation
Interchannel	Covered interval	?	?	Guinda Formation
Channel 16	Shale	G	e	Guinda Formation
Channel 16	Ss, massive bedded, planar laminated, ripple laminated, concretionary, amalgamated beds	B	abc	Guinda Formation
Channel 16	Shale	G	e	Guinda Formation
Channel 16	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated	B	abc	Guinda Formation
Channel 16	Cgl, massive bedded, planar laminated	A	ab	Guinda Formation

South Fork Willow Creek

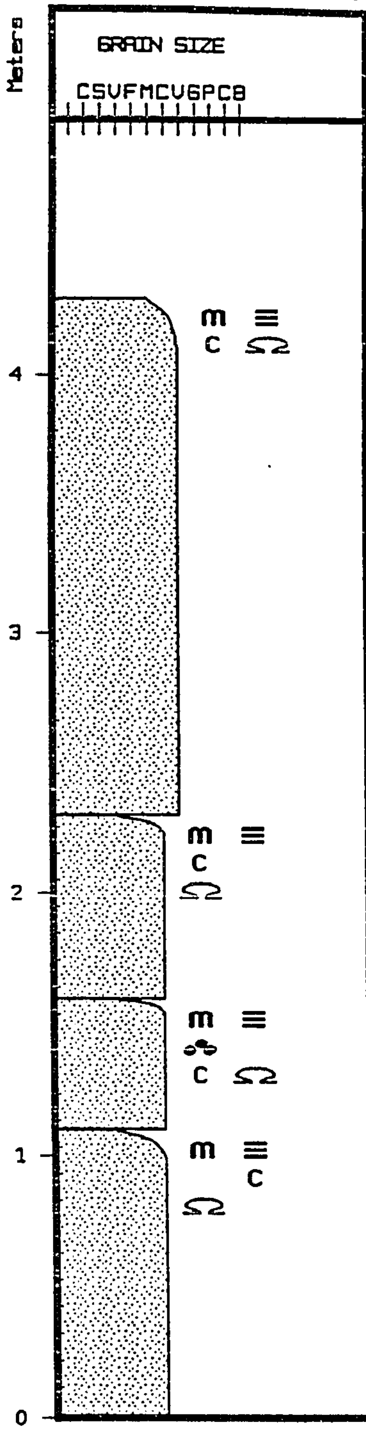
NW SE Sec. 9 T.19N. R.4W. MDBM

Glenn County, California



Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

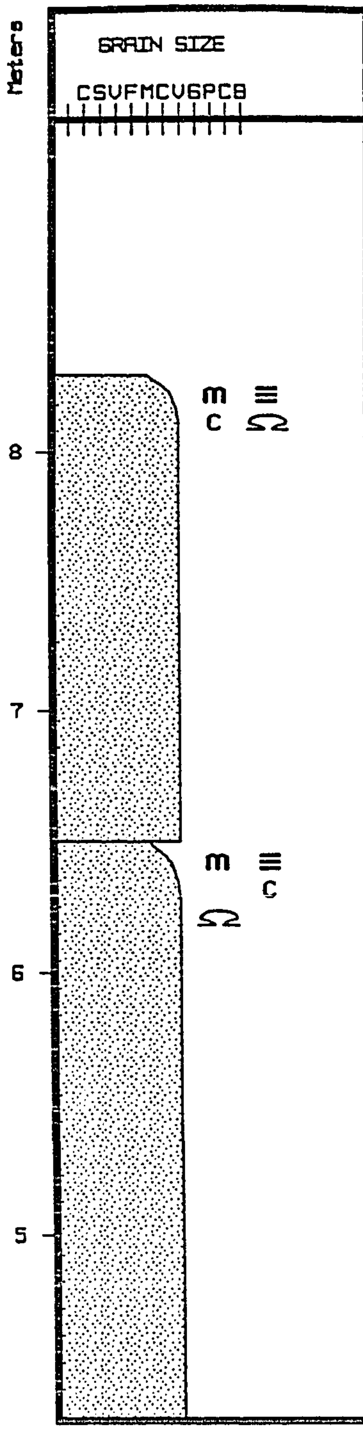
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 4	Ss, massive bedded, planar laminated, concretionary, dewatering structure, scoured base, 12 cm of downcutting, swirly laminated at base	B	ab	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, concretionary, dewatering structure	B	ab	
Channel 2	Ss, massive bedded, planar laminated, shale rip-up clasts, concretionary dewatering structure	B	ab	
Channel 1	Ss, massive bedded, planar laminated, concretionary, dewatering structure, sample 90-DBS-28SS, base covered	B	ab	

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

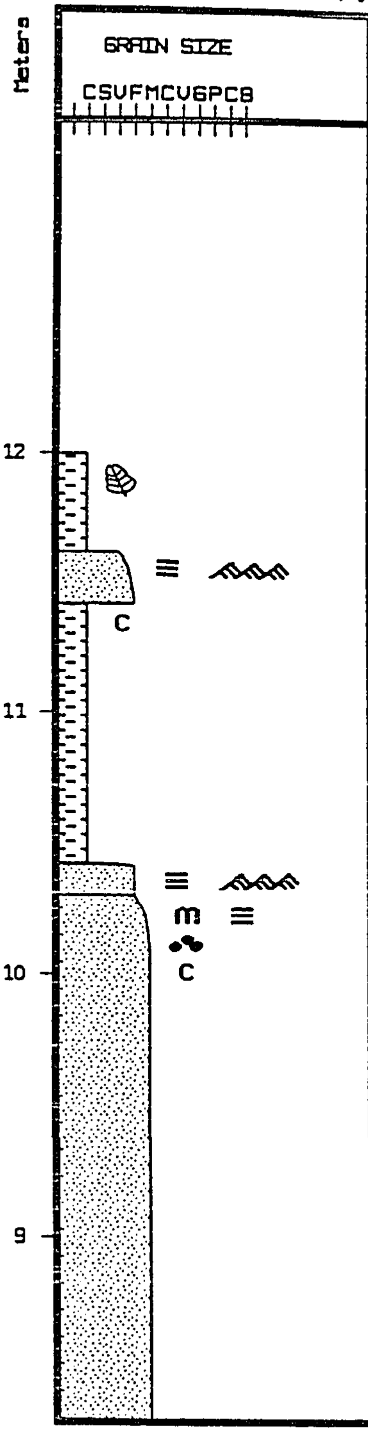
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 6	Sa, massive bedded, planar laminated, concretionary, dewatering structure	B	ab	Guinda Formation
Channel 5	Sa, massive bedded, planar laminated, concretionary, dewatering structure	B	ab	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

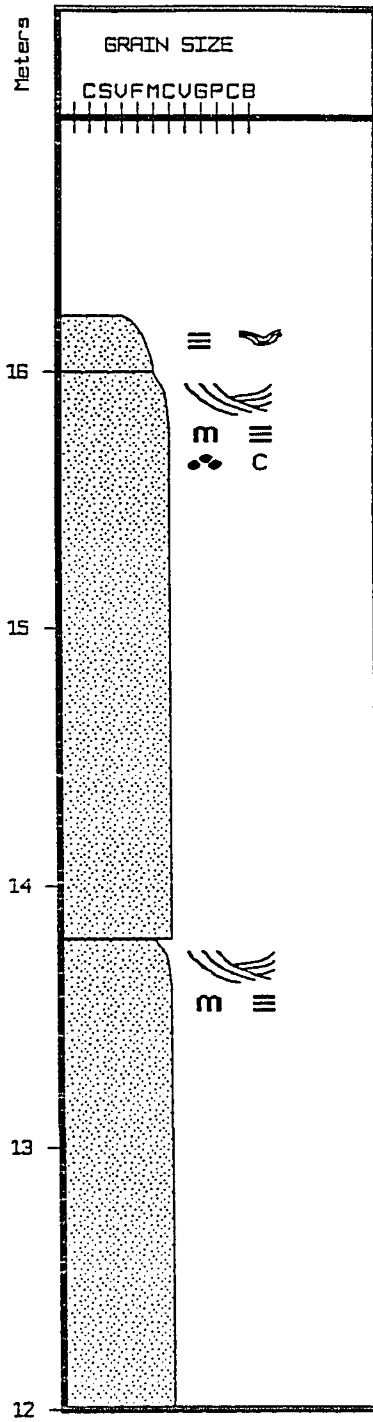
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 7	Shale, carbonaceous material	6	e	Guinda Formation
Channel 7	Ss, planar laminated, ripple laminated, poorly exposed	D	bcde	Guinda Formation
Channel 7	Shale, concretionary, sample 90-DBS-34SH	6	e	Guinda Formation
Channel 7	Ss, planar laminated, ripple laminated	B	ab	Guinda Formation
Channel 7	Ss, massive bedded, planar laminated, shale rip-up clasts, concretionary	B	ab	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

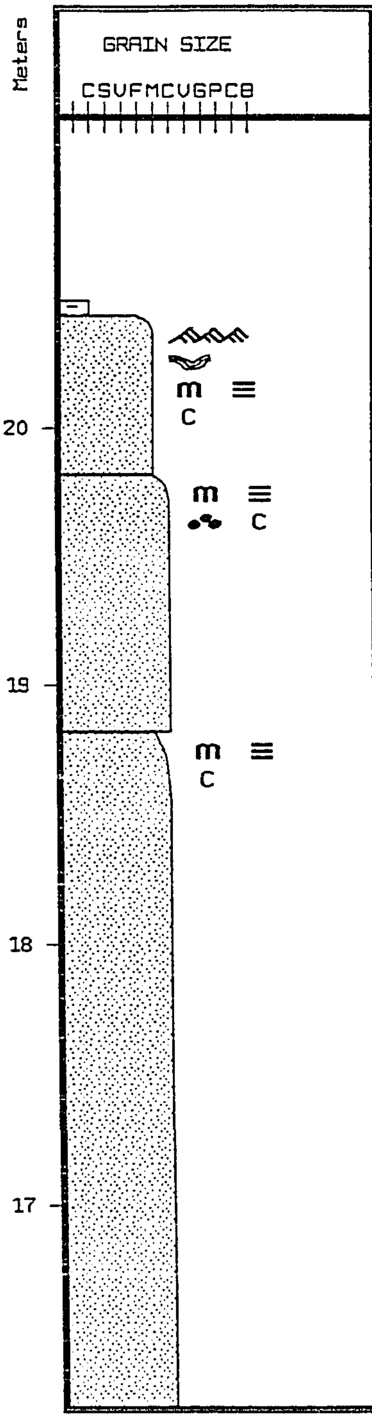
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 9	Ss, planar laminated, convolute laminated, shale partings at top	D	bc	Guinda Formation
Channel 9	Ss, massive bedded, planar laminated, trough cross stratified, shale rip-up clasts, concretionary, amalgamated beds	B	ab	Guinda Formation
Channel 8	Ss, massive bedded, planar laminated, trough cross stratified, amalgamated beds	B	ab	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

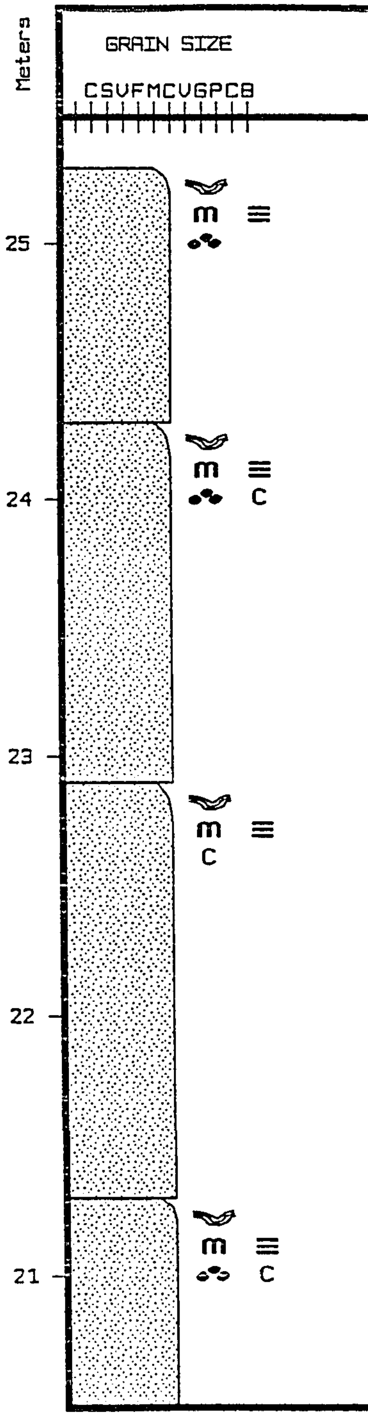
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Shale, thin interbeds of vf ss	G	e	
	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated, concretionary, amalgamated beds, sample 90-DBS-29SS	B	abc	
	Ss, massive bedded, planar laminated, shale rip-up clasts, concretionary	B	ab	
Channel 10	Ss, massive bedded, planar laminated, concretionary, amalgamated beds, scoured base, 8 cm of downcutting	B	ab	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

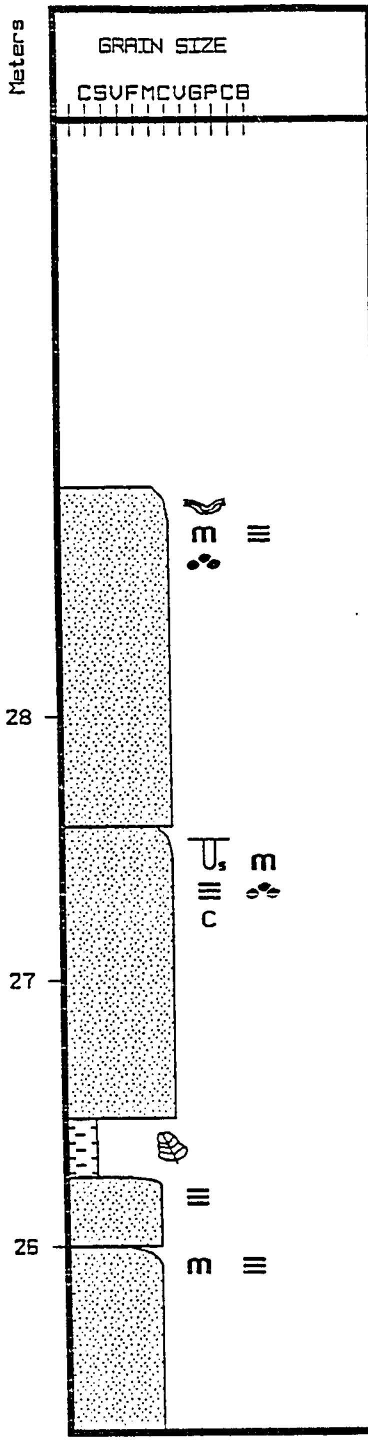
Colusa County, California



Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
25	Channel 14	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, amalgamated beds	B	abc	Guinda Formation
24	Channel 13	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, concretionary	B	abc	
23–22	Channel 12	Ss, massive bedded, planar laminated, convolute laminated, concretionary, amalgamated beds	B	abc	
21	Channel 11	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, concretionary, amalgamated beds	B	abc	

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

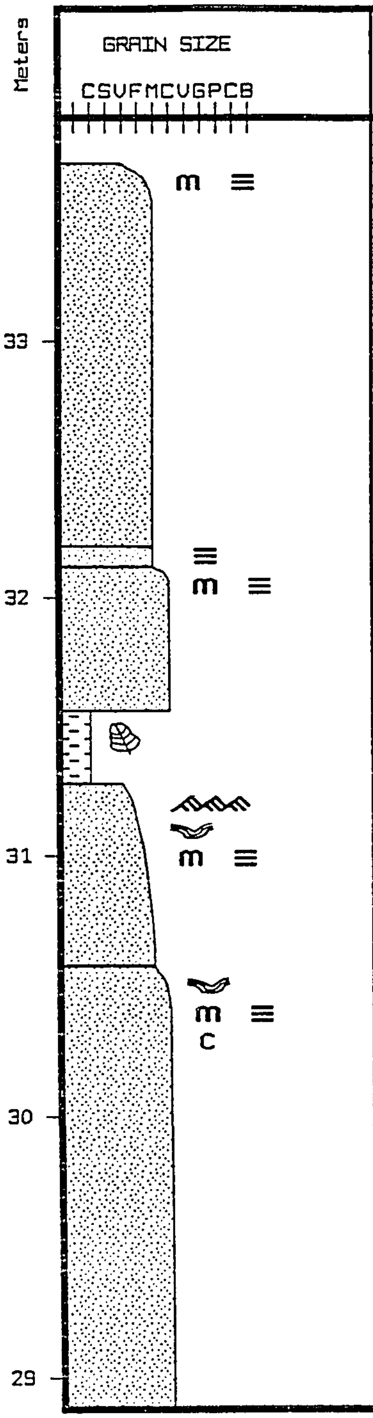
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 17	Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts, amalgamated beds	B	abc	Guinda Formation
Channel 16	Ss, massive bedded, planar laminated, shale rip-up clasts, concretionary, slightly burrowed, amalgamated beds, scattered <u>Ophiomorpha</u> burrows	B	ab	
Channel 15	Shale, carbonaceous material	G	e	
	Ss, planar laminated, sample 90-DBS-38SS	B	b	
	Ss, massive bedded, planar laminated, wavy laminations	B	ab	

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

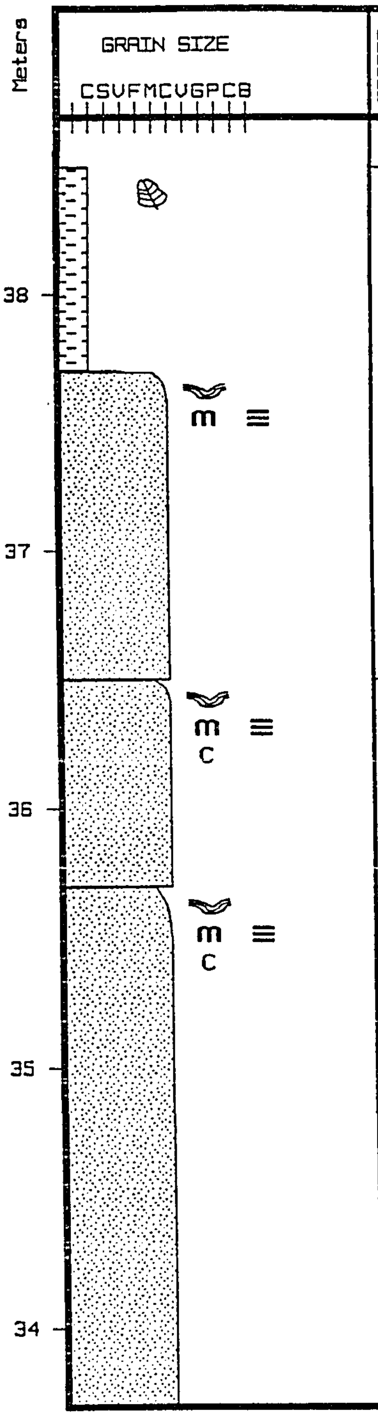
Colusa County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 19	Ss, massive bedded, planar laminated, amalgamated beds	B	ab	Guinda Formation
Channel 19	Ss, planar laminated	B	b	Guinda Formation
Channel 19	Ss, massive bedded, planar laminated, sample 90-DBS-30SS	B	ab	Guinda Formation
Channel 18	Shale, carbonaceous material	G	e	Guinda Formation
Channel 18	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated,	B	abce	Guinda Formation
Channel 18	Ss, massive bedded, planar laminated, convolute laminated, concretionary, amalgamated beds	B	abc	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

Colusa County, California



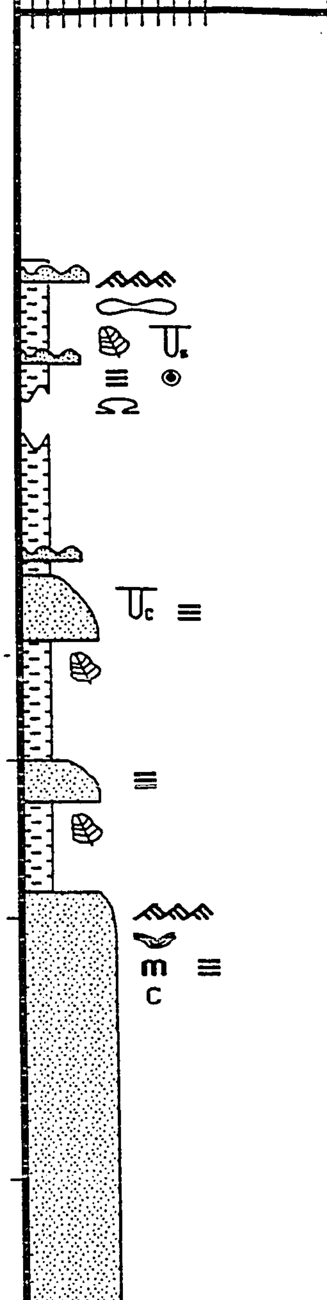
FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 22	Shale, carbonaceous material	G	e	Guinda Formation
Channel 22	Ss, massive bedded, planar laminated, convolute laminated	B	abc	Guinda Formation
Channel 21	Ss, massive bedded, planar laminated, convolute laminated, concretionary, amalgamated beds	B	abc	Guinda Formation
Channel 20	Ss, massive bedded, planar laminated, convolute laminated, concretionary	B	abc	Guinda Formation

Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

Colusa County, California

Meters — thickness = 7.5 m

GRAIN SIZE
CSVFMCVGPCB

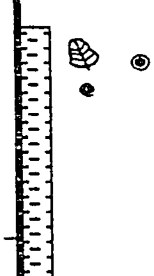


41
40
39

FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:3), planar laminated, ripple laminated, concretionary, carbonaceous material/charcoal, dewatering structure, pinch and swell, slightly burrowed, max bed thickness=15cm	DE G	cde	Guinda Formation
Crevasse Splay 2	Ss, planar laminated, completely burrowed	D	bce	Guinda Formation
IC	Shale, carbonaceous material	G	e	Guinda Formation
Crevasse Splay 1	Ss, planar laminated, poorly exposed	D	bce	Guinda Formation
Channel 23	Shale, carbonaceous material/charcoal	G	e	Guinda Formation
Channel 23	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated, concretionary, erosional base, 10 cm of downcutting, Sample 90-OBS-31SS	B	abcd	Guinda Formation

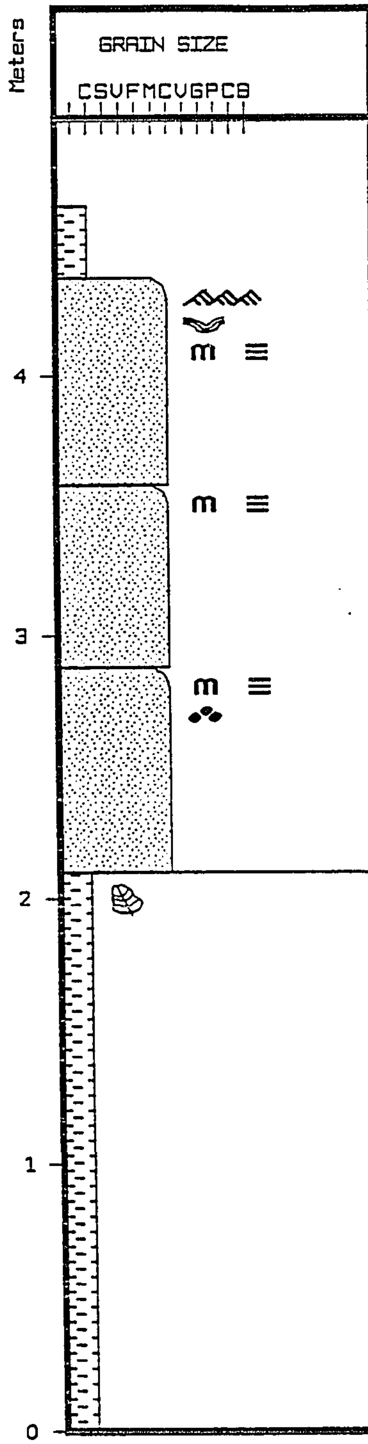
Salt Creek, Capay Hills
C SE Sec. 33 T.13N. R.3W. MDBM

Colusa County, California

Meters	GRAIN SIZE C S VF F M C VC G P C B	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
49		Basin Plain	Shale, concretionary, shells/shell fragments, carbonaceous material/charcoal, total thickness not measured, sample 90-DBS-37SH, retrieved 80 cm above last bed	6	e	Dobbins Shale Member

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

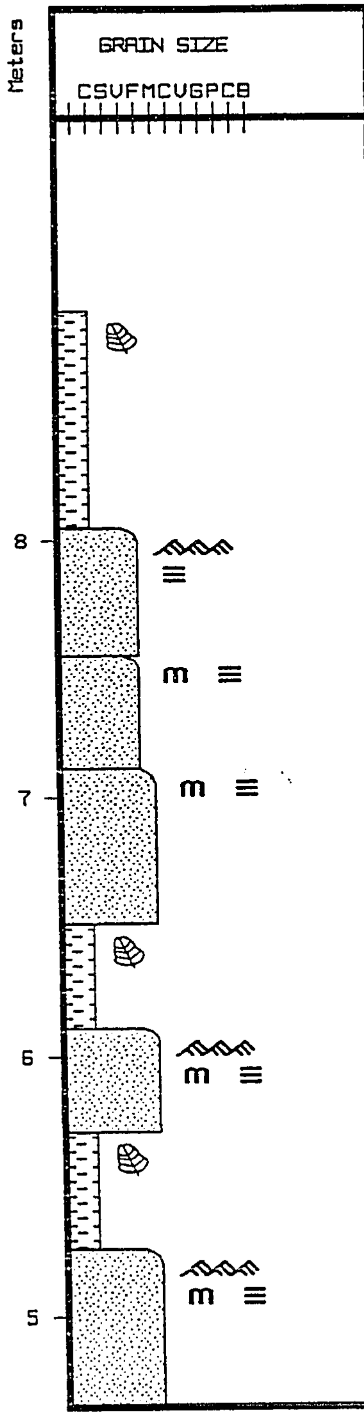
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 1	Shale	G	e	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated, sample 90-DBS-145S	B	abc	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, poorly exposed	B	ab	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, shale rip-up clasts, poorly exposed	B	ab	Guinda Formation
Basin Plain	Shale, carbonaceous material/charcoal, poorly exposed, base covered, total thickness not measured	G	e	Funks Formation

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

Yolo County, California



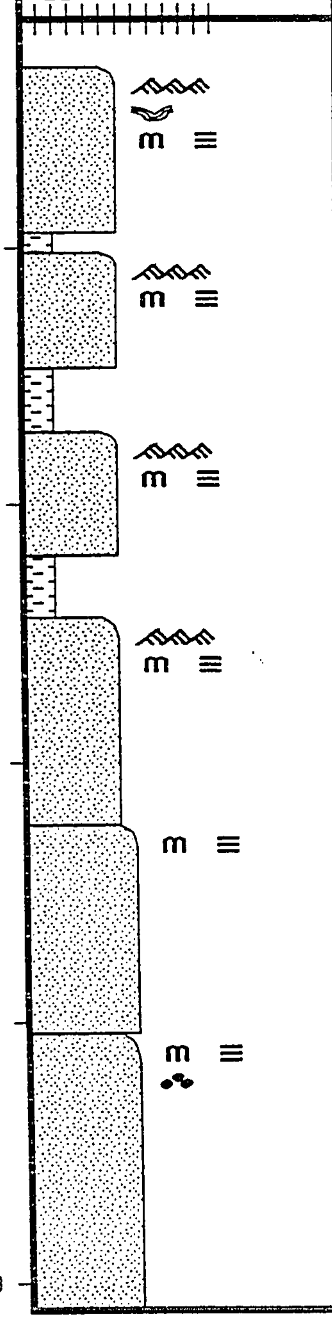
FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 1	Shale, carbonaceous material/charcoal	G	e	Guinda Formation
Channel 1	Ss, planar laminated, ripple laminated	B0	b	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, shale at top	B	ab	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 1	Shale, carbonaceous material/charcoal	G	e	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, ripple laminated, poorly exposed	B	abc	Guinda Formation
Channel 1	Shale, carbonaceous material/charcoal, sample 90-DBS-46SH (retrieved approx. 30 m laterally to north)	G	e	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, ripple laminated, poorly exposed	B	abc	Guinda Formation

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

Yolo County, California

Meters: 13, 12, 11, 10, 9

GRAIN SIZE
CSVFMCVGPCB

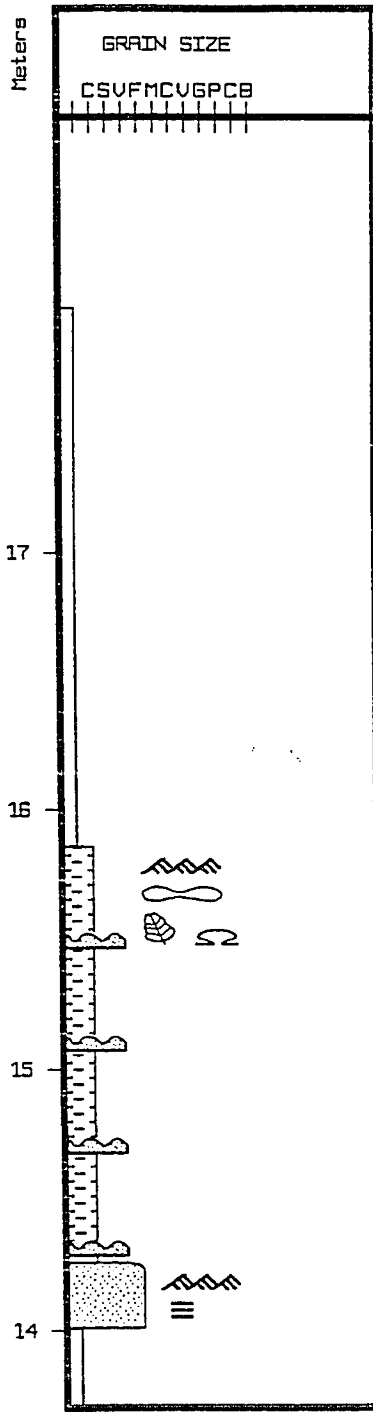


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 2	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated	B	abc	Guinda Formation
	Shale	G	e	
	Ss, massive bedded, planar laminated, ripple laminated, poorly exposed	B	abc	
	Shale	G	e	
	Ss, massive bedded, planar laminated, ripple laminated	B	abc	
	Shale, poorly exposed	G	e	
	Ss, massive bedded, planar laminated, ripple laminated	B	abc	
	Ss, massive bedded, planar laminated, shale at top	B	ab	
	Ss, massive bedded, planar laminated, shale rip-up clasts, scoured base, 8 cm of downcutting	B	ab	

Putah Creek, North Side

SE SE Sec. 21 T.8N. R.2W. MDBM

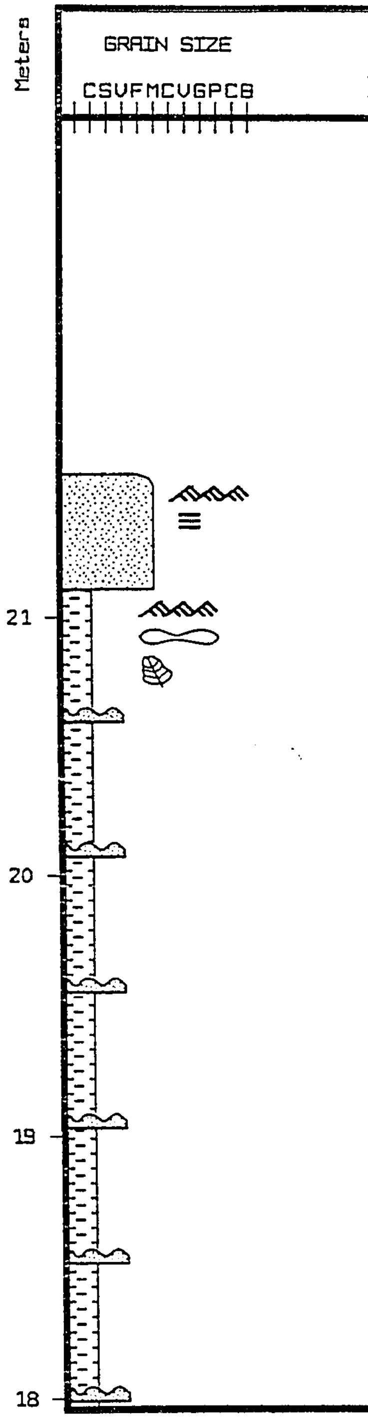
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Levee	Covered interval	?	?	Guinda Formation
Channel 2	Interbedded shale and ss (ss:sh = 1:5), ripple laminated, carbonaceous material/charcoal, dewatering structure, pinch and swell, max bed thickness=6 cm	DE G	cde	
	Ss, planar laminated, ripple laminated	BD	bc	
	Covered interval	?	?	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

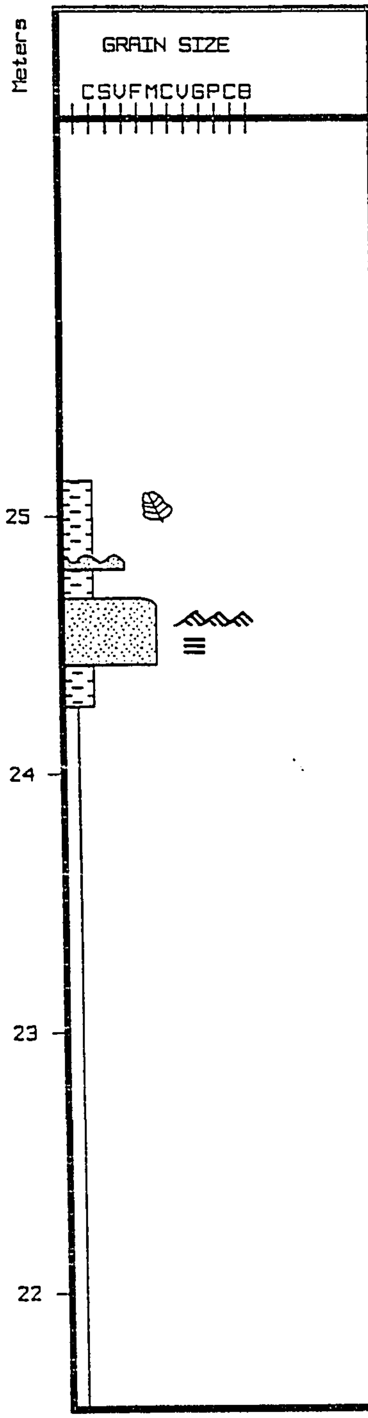
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Levee	Ss, planar laminated, ripple laminated, poorly exposed	D	cde	Guinda Formation
	Interbedded shale and ss (ss:sh = 1:7), ripple laminated, carbonaceous material/charcoal, pinch and swell, laterally discontinuous, max bed thickness=8 cm	DE	cde	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

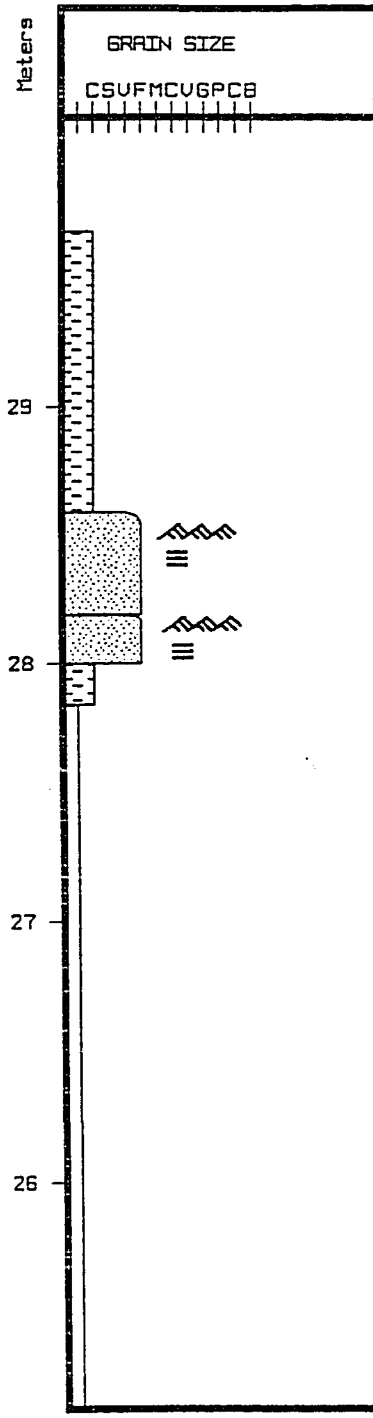
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:7), carbonaceous material/charcoal, max bed thickness=6 cm, poorly exposed	DE 6	cde	Guinda Formation
Levee	Ss, planar laminated, ripple laminated, poorly exposed	D	cde	
	Shale	G	e	
	Covered interval	?	?	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

Yolo County, California

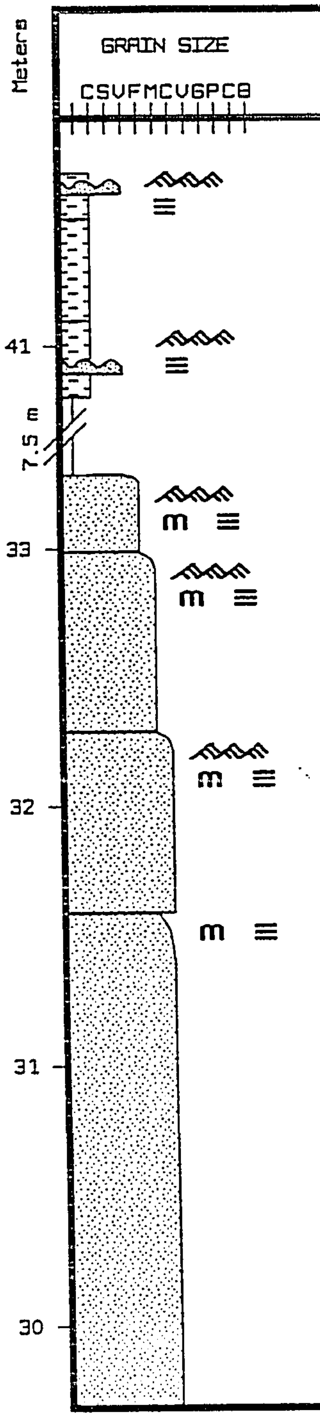


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Shale, poorly exposed	G	e	Guinda Formation
	Ss, planar laminated, ripple laminated, poorly exposed	D	bc	
	Ss, planar laminated, ripple laminated, poorly exposed	D	bc	
	Shale	G	e	
	Covered interval, some fine-grained sandstone float present	?	?	

Putah Creek, North Side

SE SE Sec. 21 T.8N. R.2W. MDBM

Yolo County, California

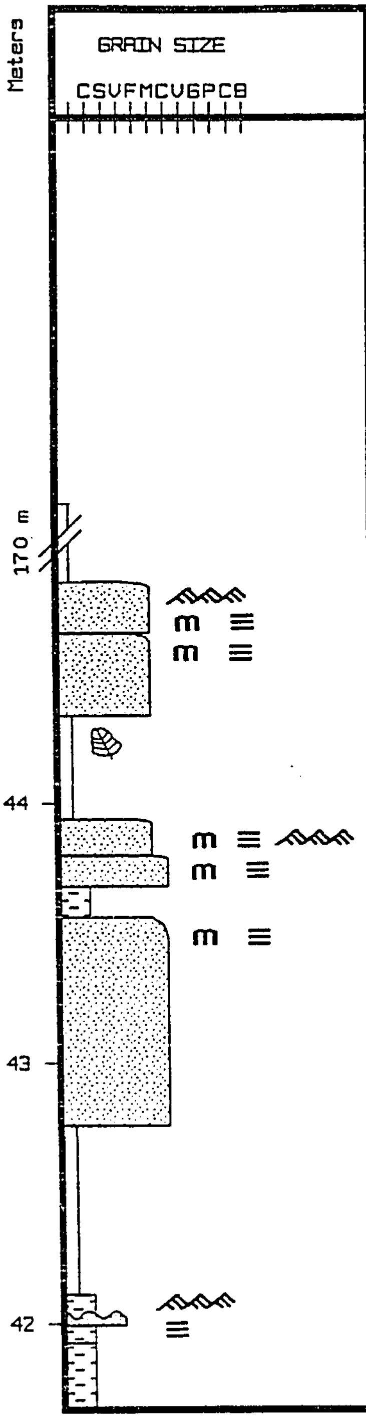


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation
Interchannel	Shale	G	e	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation
Interchannel	Covered interval	?	?	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, ripple laminated, shale at top	B	abc	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, ripple laminated	B	abc	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, ripple laminated	B	ab	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, scoured base, 6 cm of downcutting	B	ab	Guinda Formation

Putah Creek, North Side

SE SE Sec. 21 T.8N. R.2W. MDBM

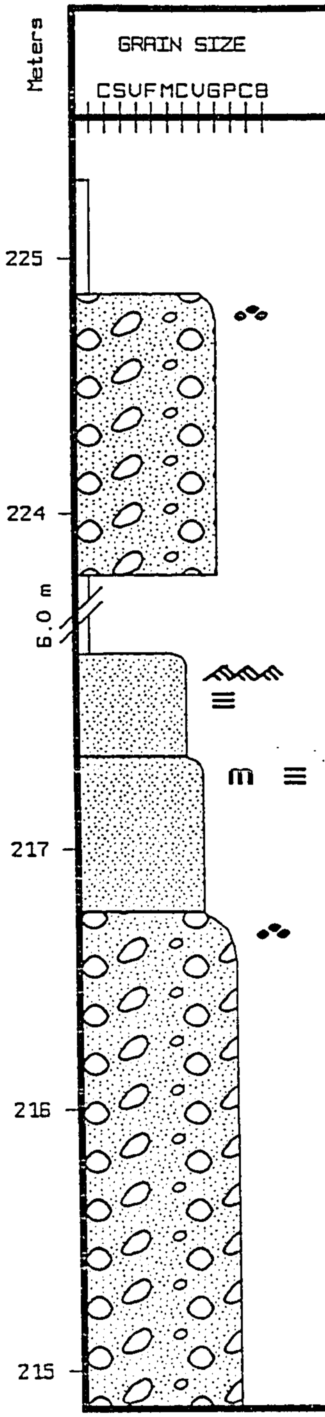
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Inter-chan-nel	Covered interval, sandstone and conglomerate float	?	?	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated, ripple laminated	B	abc	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 4	Covered interval, carbonaceous material	?	?	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated, ripple laminated, poorly exposed	B	abc	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 4	Shale	G	e	Guinda Formation
Channel 4	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Interchannel	Covered interval	?	?	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation
Interchannel	Shale	G	e	Guinda Formation

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

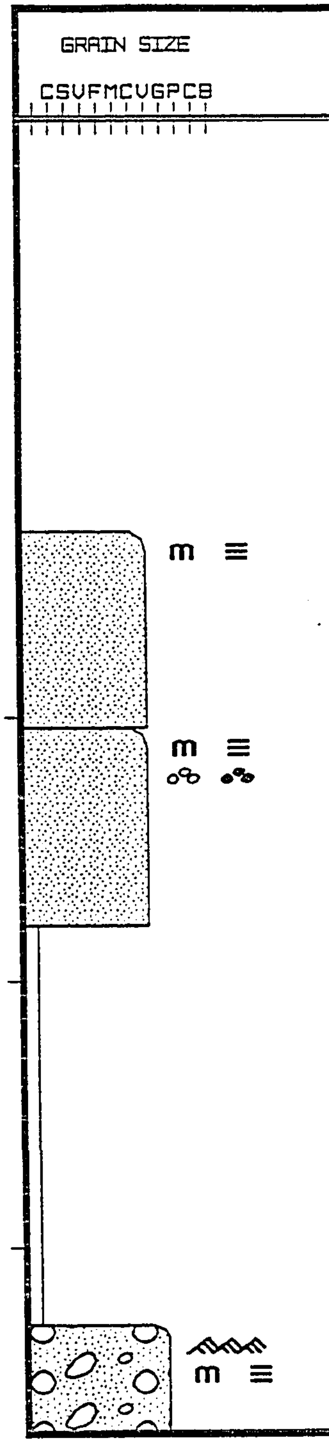
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 6	Covered interval	?	?	Guinda Formation
Channel 6	Conglomerate with ss matrix, shale rip-up clasts, 5 cm max clast size, sandstone lenses, scoured base, 6 cm of downcutting	A	ab	
Inter-channel	Covered interval, scattered sandstone float	?	?	
Channel 5	Ss, planar laminated, ripple laminated, shale at top	B	ab	
	Ss, massive bedded, planar laminated	B	ab	
	Conglomerate with ss matrix, shale rip-up clasts, 5 cm max clast size, sandstone lenses, scoured base, 6 cm of downcutting	A	ab	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

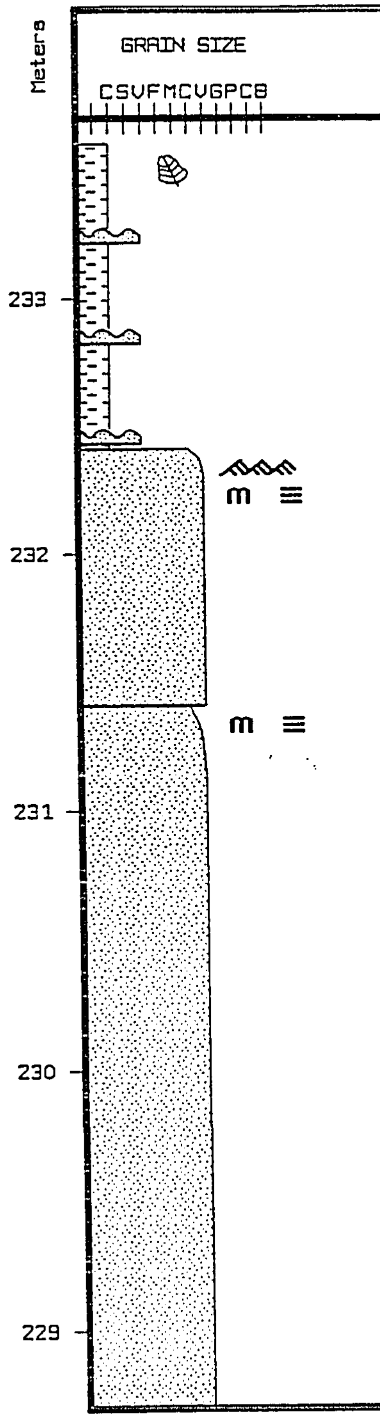
Yolo County, California



Meters	Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
	Channel 7	Ss, massive bedded, planar laminated	A	ab	Guinda Formation
228	Channel 7	Ss, massive bedded, planar laminated, pebbles, shale rip-up clasts, 1-cm pebbles at base, scoured base, 6 cm of downcutting	A	ab	Guinda Formation
227	Interchannel	Covered interval	?	?	Guinda Formation
226					
	Channel 6	Conglomerate with ss matrix, massive bedded, planar laminated, ripple laminated, shale at top	A	ab	Guinda Formation

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

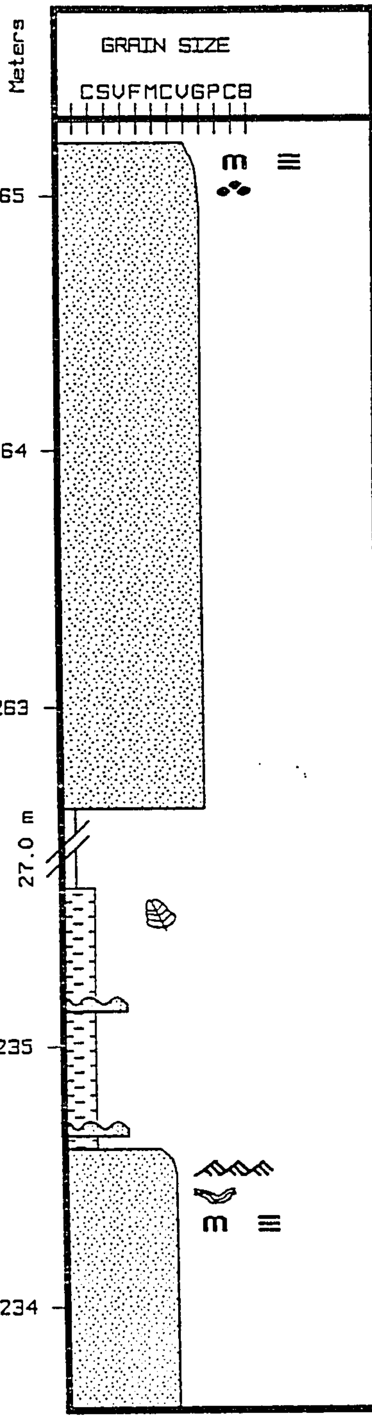
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:5), carbonaceous material/charcoal, max bed thickness=6 cm, poorly exposed	DE G	cde	Guinda Formation
Channel 7	Ss, massive bedded, planar laminated, ripple laminated	A	abc	
	Ss, massive bedded, planar laminated	A	ab	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

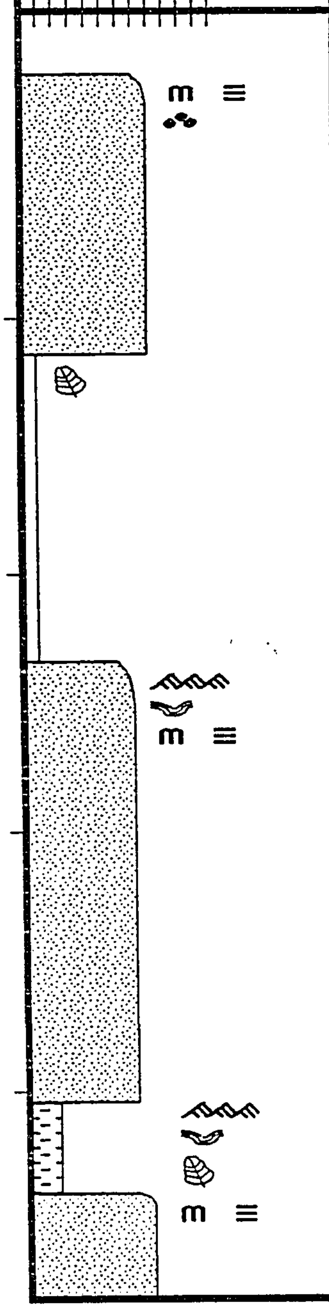
Yolo County, California



Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
Channel 8	Ss, massive bedded, planar laminated, shale rip-up clasts	A	ab	Guinda Formation
Channel 8	Covered interval	?	?	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:5), carbonaceous material/charcoal, max bed thickness=6 cm, poorly exposed	DE G	cde	Guinda Formation
Crevasse Splay	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated	CE	abce	Guinda Formation

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

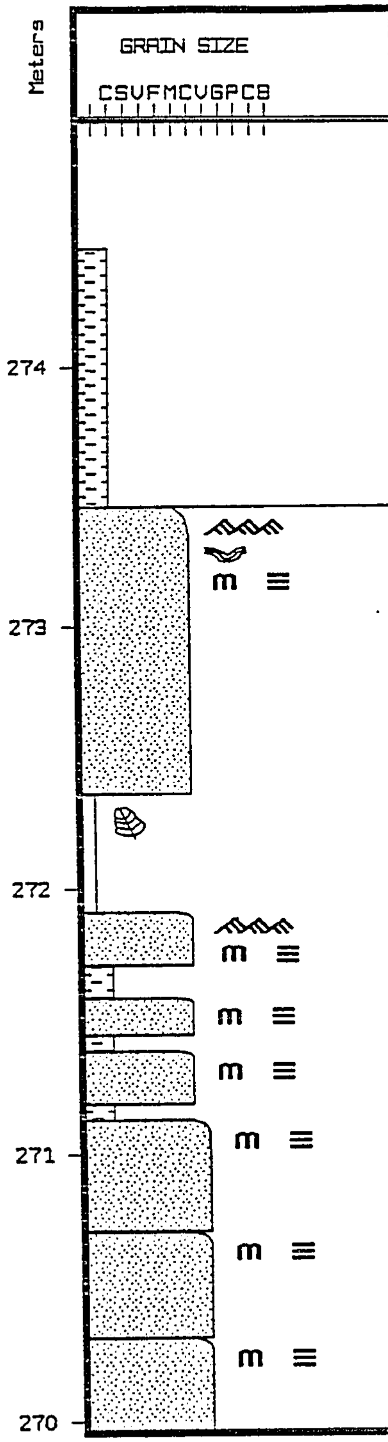
Yolo County, California



Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Channel 9	Ss, massive bedded, planar laminated, shale rip-up clasts, scoured base, 6 cm of downcutting	A	ab	Guinda Formation
269	Channel 8	Covered interval, carbonaceous material	?	?	
268		Ss, massive bedded, planar laminated, ripple laminated, convolute laminated	G	e	
267					
266		Shale, ripple laminated, convolute laminated, carbonaceous material/chercoal, sample 90-DBS-40SH	DE G	cde	
		Ss, massive bedded, planar laminated	B	ab	

Putah Creek, North Side
SE SE Sec. 21 T.8N. R.2W. MDBM

Yolo County, California

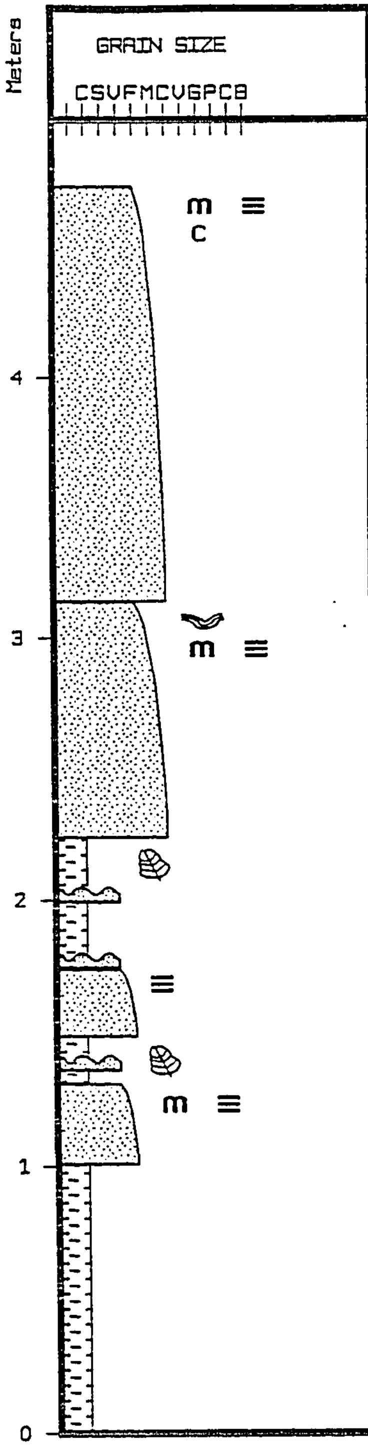


Meters	Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
274	Basin Plain	Shale, total thickness not measured	G	e	Dobbins Shale Member
273	Channel 9	Ss, massive bedded, planar laminated, ripple laminated, convolute laminated, sample 90-DBS-125S	B	abc	Guinda Formation
	Channel 9	Covered interval, carbonaceous material	?	?	Guinda Formation
272	Channel 9	Ss, massive bedded, planar laminated, ripple laminated	B	abc	Guinda Formation
	Channel 9	Shale	G	e	Guinda Formation
	Channel 9	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
	Channel 9	Shale	G	e	Guinda Formation
	Channel 9	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
	Channel 9	Shale	G	e	Guinda Formation
271	Channel 9	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
	Channel 9	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
270	Channel 9	Ss, massive bedded, planar laminated, scoured base, 8 cm of downcutting	B	ab	Guinda Formation

Ulatis Creek/Mix Canyon

NW SW Sec. 34 T.7N. R.2W. MDBM

Solano County, California

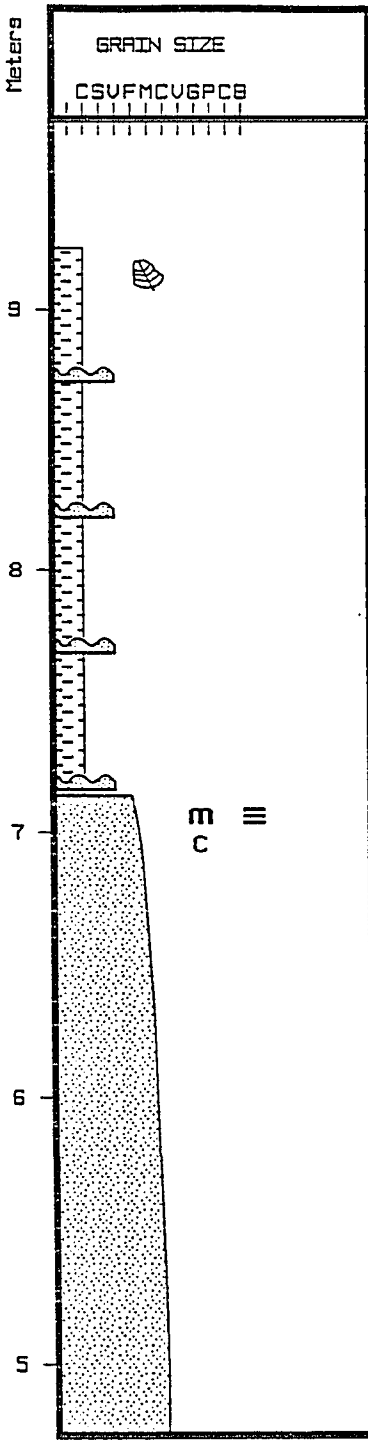


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 2	Ss, massive bedded, planar laminated, concretionary, numerous small-scale faults, scoured base, 16 cm of downcutting	B	ab	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, convolute laminated, scoured base, 4 cm of downcutting, sample 90-DBS-04SS	B	ab	
Interchannel	Interbedded shale and ss (ss:sh = 1:3), carbonaceous material/charcoal, thin interbeds of f ss	EG	ce	
	Ss, planar laminated	CD G	bce	
	Interbedded shale and ss (ss:sh = 1:3), carbonaceous material/charcoal, thin interbeds of f ss, sample 90-DBS-17SH	EG	be	
	Ss, massive bedded, planar laminated, poorly exposed	C	abc	
Basin Plain	Shale, poorly exposed, base covered	G	e	

Ulatis Creek/Mix Canyon

NW SW Sec. 34 T.7N. R.2W. MDBM

Solano County, California

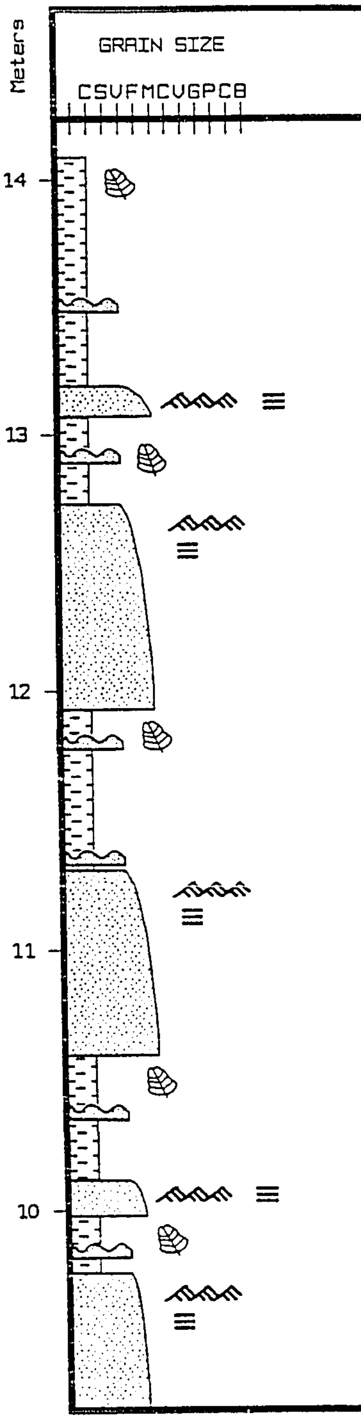


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel	Interbedded shale and ss (ss:sh = 1:7), carbonaceous material/charcoal, thin interbeds of f ss	EG	ce	Guinda Formation
Channel 3	Ss, massive bedded, planar laminated, concretionary, amalgamated beds	B	ab	

Ulatis Creek/Mix Canyon

NW SW Sec. 34 T.7N. R.2W. MDBM

Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Interchannel/Levees	Shale, carbonaceous material/charcoal, thin interbeds of vf ss, sample 90-DBS-16SH	EG	bce	Guinda Formation
	Ss, planar laminated, ripple laminated	DG	bce	
	Interbedded shale and ss (ss:sh = 1:5), carbonaceous material/charcoal, thin interbeds of f ss	EG	bce	
	Ss, planar laminated, ripple laminated, thin interbeds of sh, sample 90-DBS-06SS	CDG	bce	
	Interbedded shale and ss (ss:sh = 1:7), carbonaceous material/charcoal, thin interbeds of f ss	EG	bce	
	Ss, planar laminated, ripple laminated	DG	bce	
	Interbedded shale and ss (ss:sh = 1:7), carbonaceous material/charcoal, thin interbeds of f ss	EG	ce	
	Ss, planar laminated, ripple laminated	D	bc	
	Interbedded shale and ss (ss:sh = 1:7), carbonaceous material/charcoal, thin interbeds of f ss	EG	ce	
	Ss, planar laminated, ripple laminated	CDG	bce	

Ulatis Creek/Mix Canyon
NW SW Sec. 34 T.7N. R.2W. MDBM

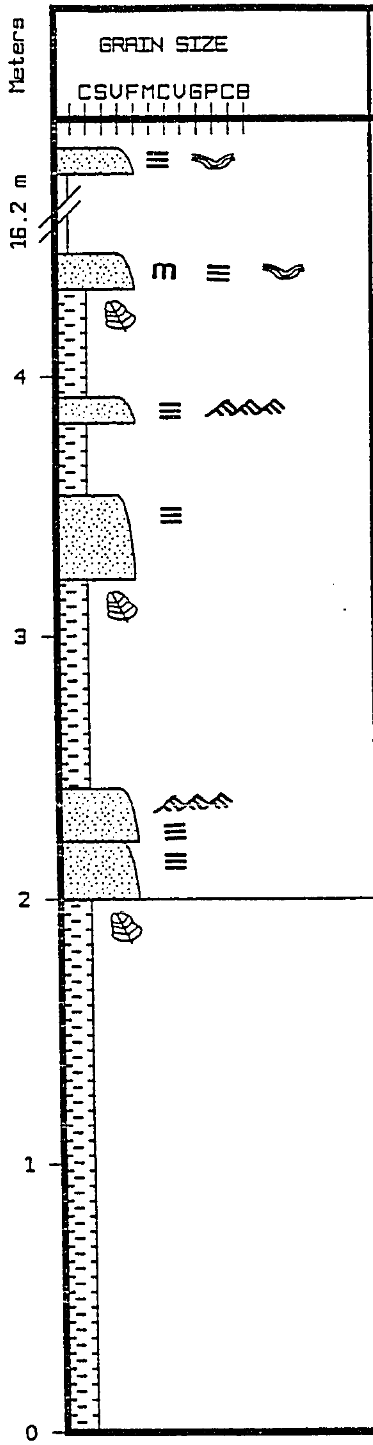
Solano County, California

Meters: 15

GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
C	Basin Plain	Shale, concretionary, carbonaceous material/charcoal, poorly exposed, total thickness not measured	G	e	Dobbins Shale
	Int-erch	Ss, planar laminated, poorly exposed	DE G	bce	Gui-nda

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



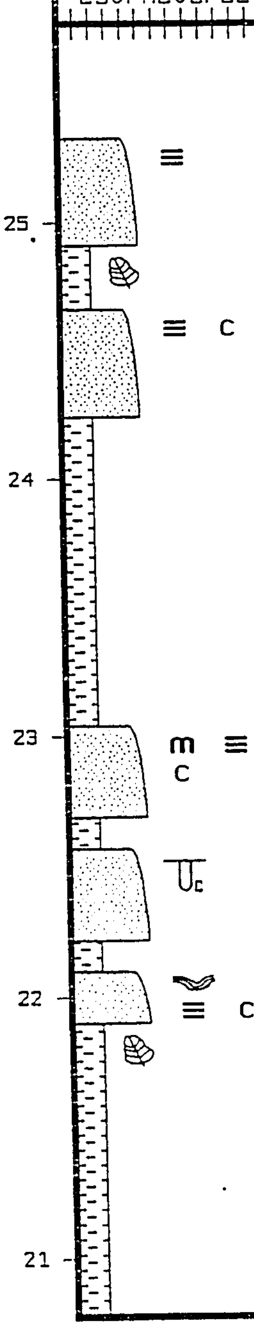
FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Fan Fringe	Ss, planar laminated, convolute laminated	D	bc	Guinda Formation
	Covered interval, some sandstone float	?	?	
	Ss, massive bedded, planar laminated, convolute laminated, scoured base, 8 cm of downcutting	CD	abc	
	Shale, carbonaceous material/charcoal	G	e	
	Ss, planar laminated, ripple laminated	D	bc	
	Shale	G	e	
	Ss, planar laminated	D	b	
	Shale, carbonaceous material/charcoal	G	b	
	Ss, planar laminated, ripple laminated	D	bc	
	Ss, planar laminated	D	b	
Basin Plain	Shale, carbonaceous material/charcoal, poorly exposed, base covered, total thickness not measured	G	b	Funks Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters: 21–25

GRAIN SIZE
CSVFMCVGPCB



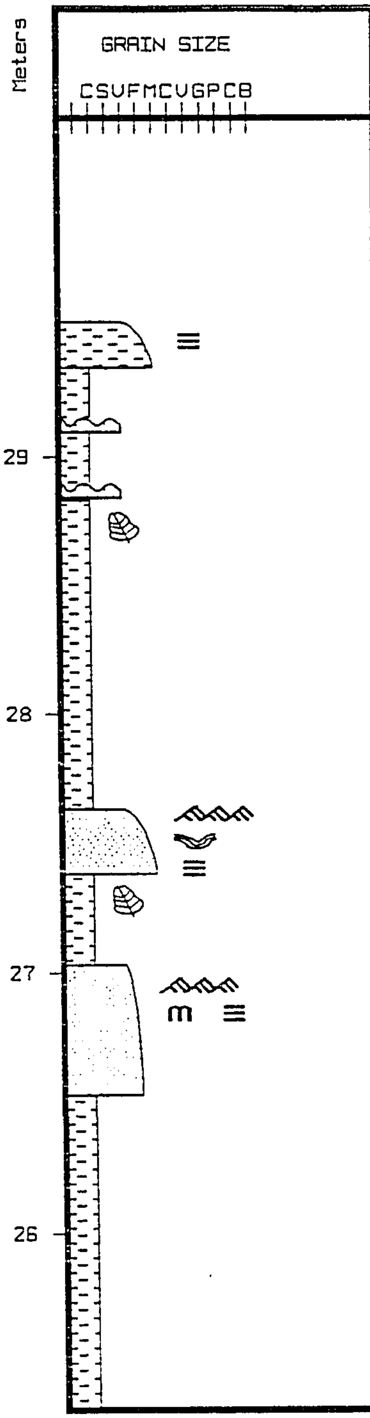
FACIES ASSOC.: Fan Fringe

FM.: Guinda Formation

ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.
Ss, planar laminated	D	b
Shale, carbonaceous material	G	e
Ss, planar laminated, concretionary	D	b
Shale	G	e
Ss, massive bedded, planar laminated, concretionary	CD	ab
Shale	G	e
Ss, completely burrowed	D	bc
Shale	G	e
Ss, planar laminated, convolute laminated, concretionary	D	bc
Shale, carbonaceous material/charcoal	G	e

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

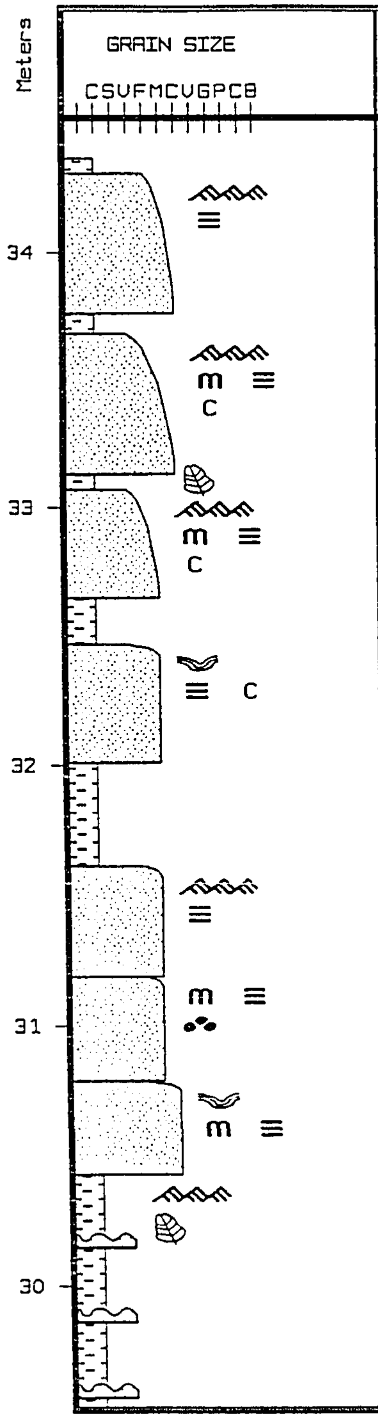


ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FACIES ASSOC.	FM.
Shale, planar laminated	G	b	Fan Fringe	Guinda Formation
Interbedded shale and ss (ss:sh = 1:3), max bed thickness=6 cm	DE G	cde	Fan Fringe	Guinda Formation
Shale, carbonaceous material/charcoal, poorly exposed	G	e	Fan Fringe	Guinda Formation
Ss, planar laminated, ripple laminated, convolute laminated	D	bc	Fan Fringe	Guinda Formation
Shale, carbonaceous material/charcoal	G	e	Fan Fringe	Guinda Formation
Ss, massive bedded, planar laminated, ripple laminated	CD	abc	Fan Fringe	Guinda Formation
Shale	G	e	Fan Fringe	Guinda Formation

Alamo Creek/Gates Canyon

SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 1	Shale	G	e	Guinda Formation
	Ss, planar laminated, ripple laminated	DG	bce	
	Shale	G	e	
	Ss, massive bedded, planar laminated, ripple laminated, concretionary	CG	ace	
	Shale, carbonaceous material	G	e	
	Ss, massive bedded, planar laminated, ripple laminated, concretionary	BG	ace	
	Shale	G	e	
	Ss, planar laminated, convolute laminated, concretionary	D	bc	
	Shale	G	e	
	Ss, planar laminated, ripple laminated	BG	ace	
	Ss, massive bedded, planar laminated, shale rip-up clasts, scoured base, 6 cm of downcutting	BG	ae	
	Ss, massive bedded, planar laminated, convolute laminated, sample 90-DBS-33SH	C	abc	
Fan Fringe	Interbedded shale and ss (ss:sh = 1:3), ripple laminated, carbonaceous material/charcoal, max bed thickness=12 cm	DE G	cde	

Alamo Creek/Gates Canyon

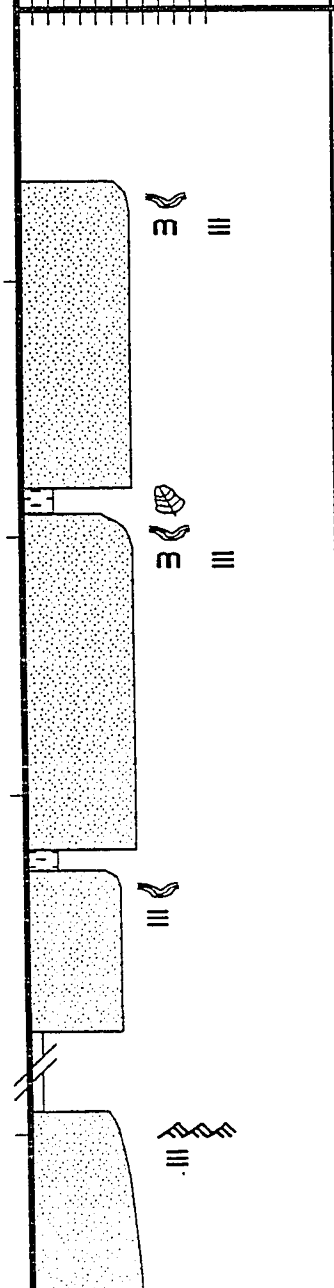
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters: 65, 64, 63, 27.0 m, 35

GRAIN SIZE

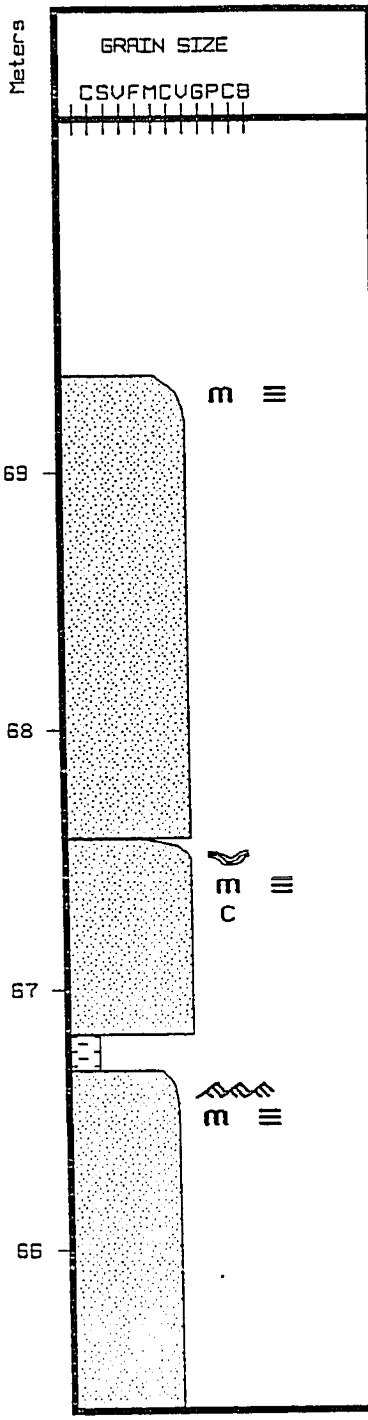
CSVFMCVGPCB



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Lobe 2	Ss, massive bedded, planar laminated, convolute laminated, shale at top	CG	ab	Guinda Formation
Lobe 2	Shale, carbonaceous material	G	e	Guinda Formation
Lobe 2	Ss, massive bedded, planar laminated, convolute laminated	C	abc	Guinda Formation
Lobe 2	Shale	G	e	Guinda Formation
Lobe 2	Ss, planar laminated, convolute laminated, poorly exposed	C	ab	Guinda Formation
Inter-lobe	Covered interval, thin beds of poorly exposed sandstone	?	?	Guinda Formation
Lobe 1	Ss, planar laminated, ripple laminated	D	bc	Guinda Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

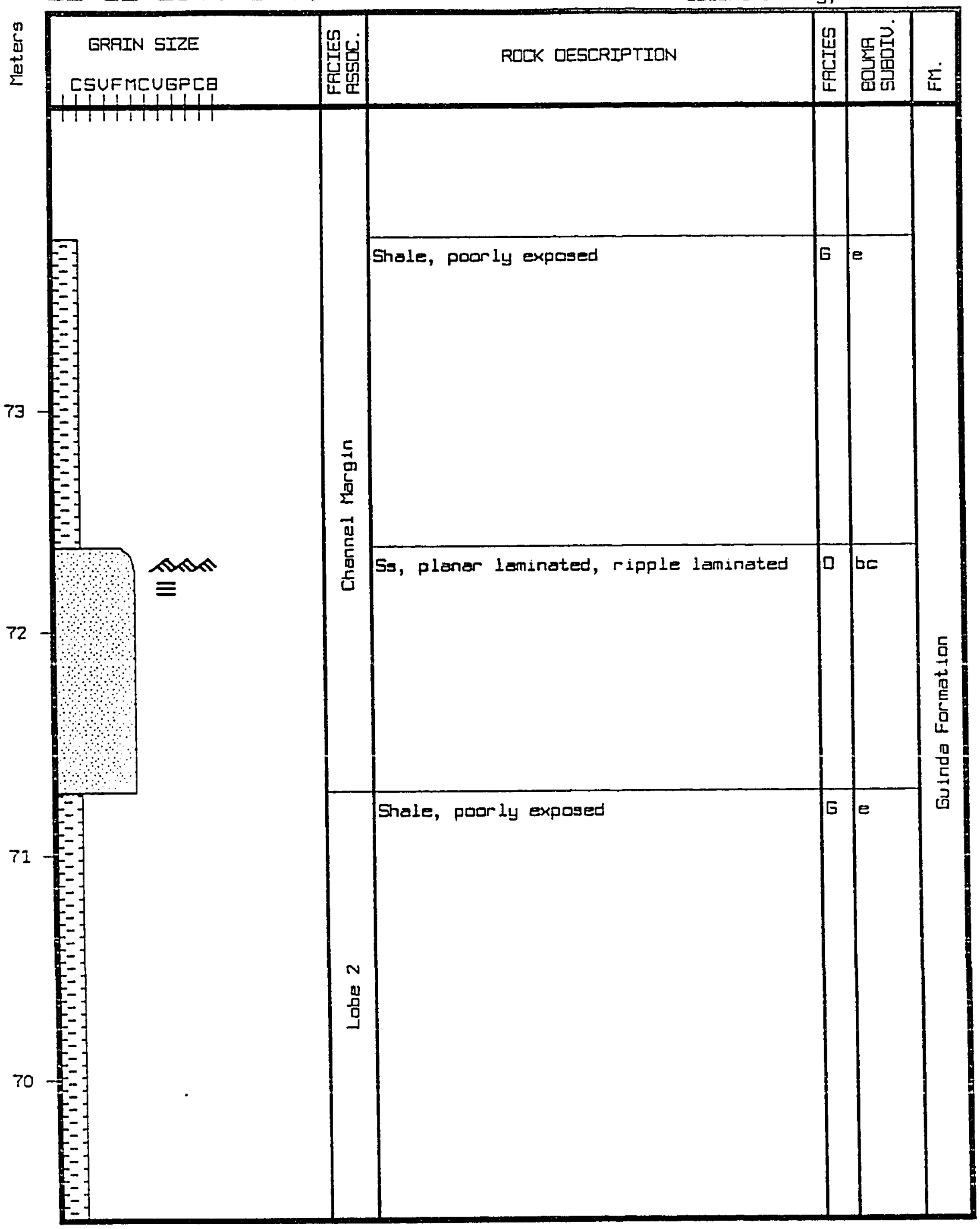


Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
Lobe 2	Ss, massive bedded, planar laminated, poorly exposed	C	ab	Guinda Formation
Lobe 2	Ss, massive bedded, planar laminated, convolute laminated, concretionary, shale at top	C	abce	Guinda Formation
Lobe 2	Shale	G	e	Guinda Formation
Lobe 2	Ss, massive bedded, planar laminated, ripple laminated	C	abc	Guinda Formation

Alamo Creek/Gates Canyon

SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

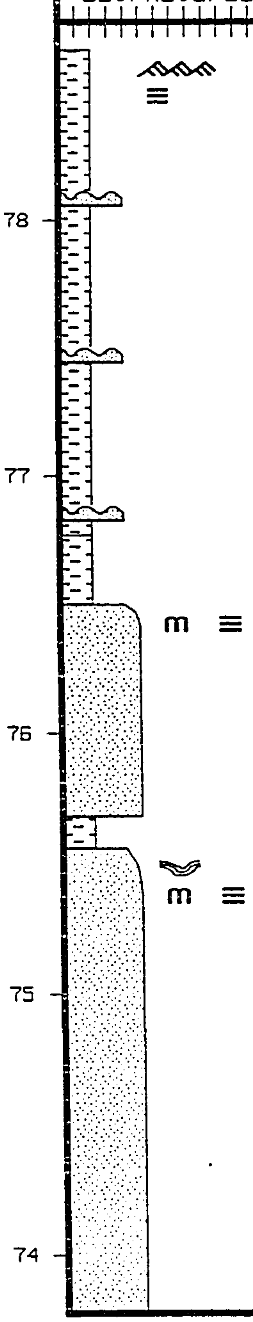


Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters

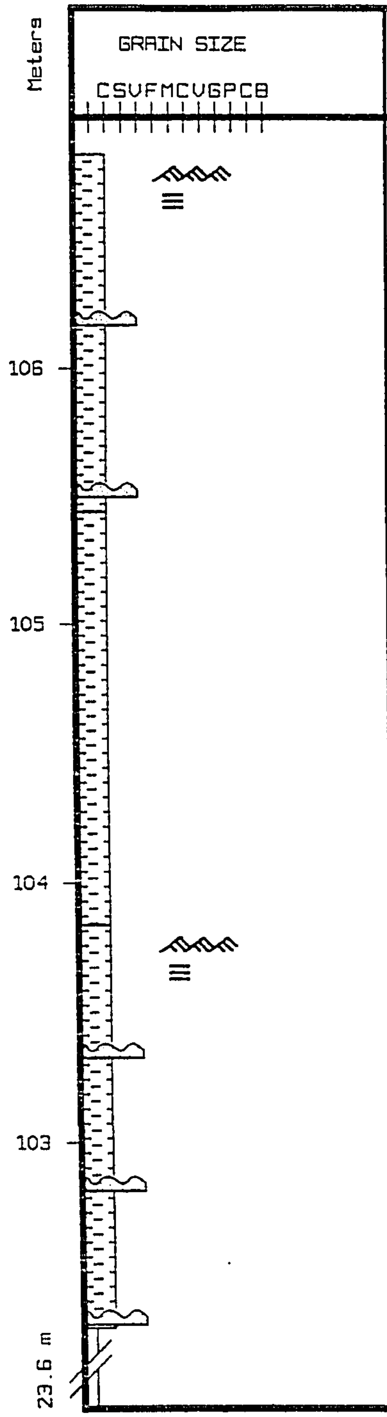
GRAIN SIZE
CSVFMCVGPCB



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel Margin	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm, poorly exposed	DE G	bce	Guinda Formation
	Shale, poorly exposed	G	e	
	Ss, massive bedded, planar laminated, poorly exposed	DE G	abe	
	Shale	G	e	
	Ss, massive bedded, planar laminated, convolute laminated	D	abc	

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



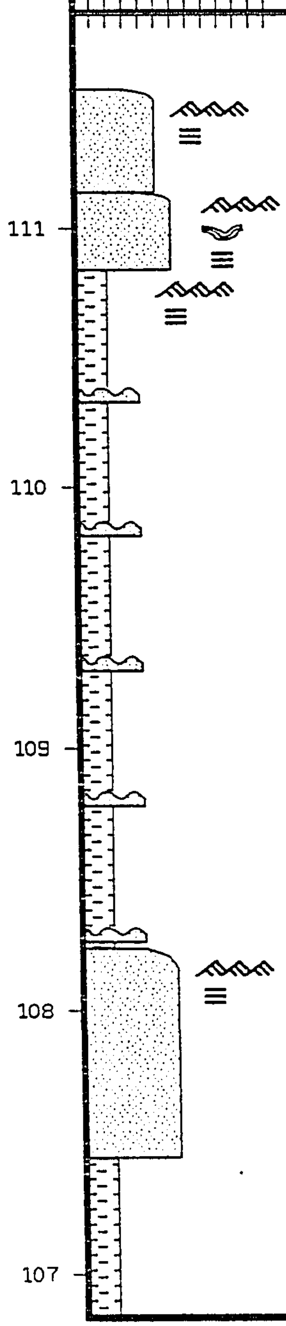
FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel Margin	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=8 cm	DE G	bce	Guinda Formation
	Shale	G'	e	
	Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	
	Covered interval	?	?	

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters: 111, 110, 109, 108, 107

GRAIN SIZE
CSVFMCVGPCB



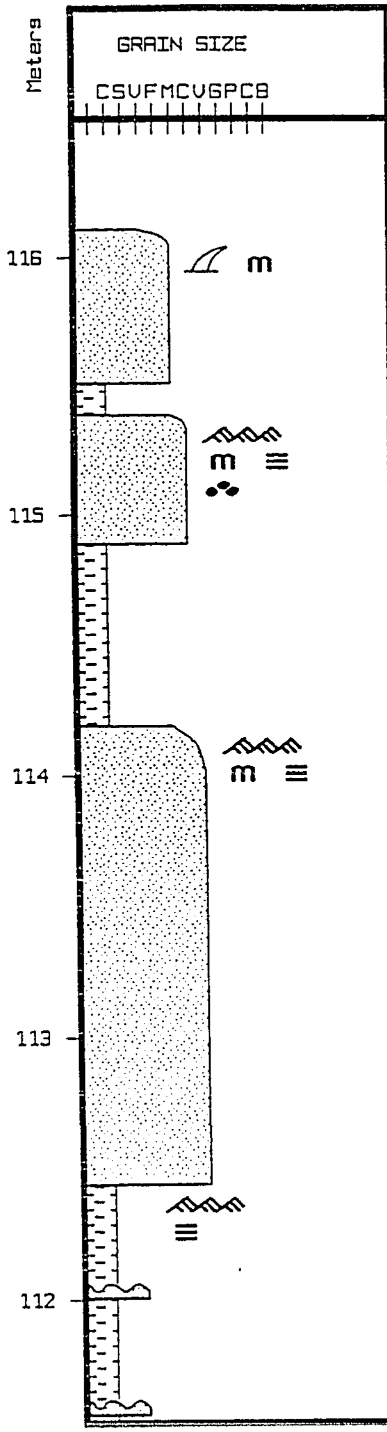
Rock Description	Facies	Bouma Subdiv.
Ss, planar laminated, ripple laminated, poorly exposed	D	bc
Ss, planar laminated, ripple laminated, convolute laminated, shale at top	D	bce
Interbedded shale and ss (ss:sh = 1:7), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce
Ss, planar laminated, ripple laminated, poorly exposed	D	bc
Shale, poorly exposed	G	e

Facies Assoc.: Channel Margin

Fm.: Guinda Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

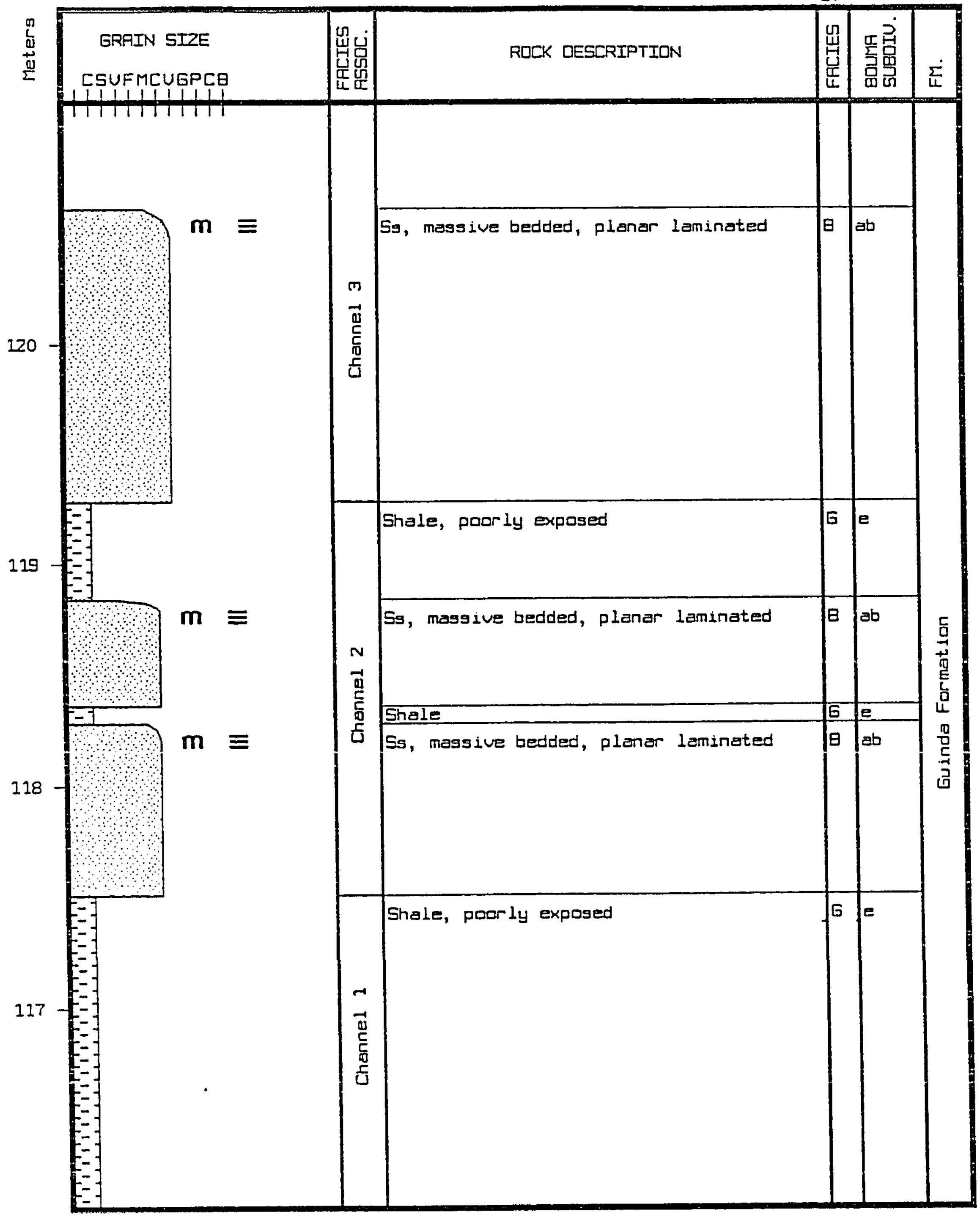


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 1	Ss, massive bedded, flame structure	B	a	Guinda Formation
Channel 1	Shale	G	e	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, ripple laminated, shale rip-up clasts	B	abc	Guinda Formation
Channel 1	Shale, poorly exposed	G	e	Guinda Formation
Channel 1	Ss, massive bedded, planar laminated, ripple laminated	B	abc	Guinda Formation
Channel Margin	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, max bed thickness=8 cm	DE G	bce	Guinda Formation

Alamo Creek/Gates Canyon

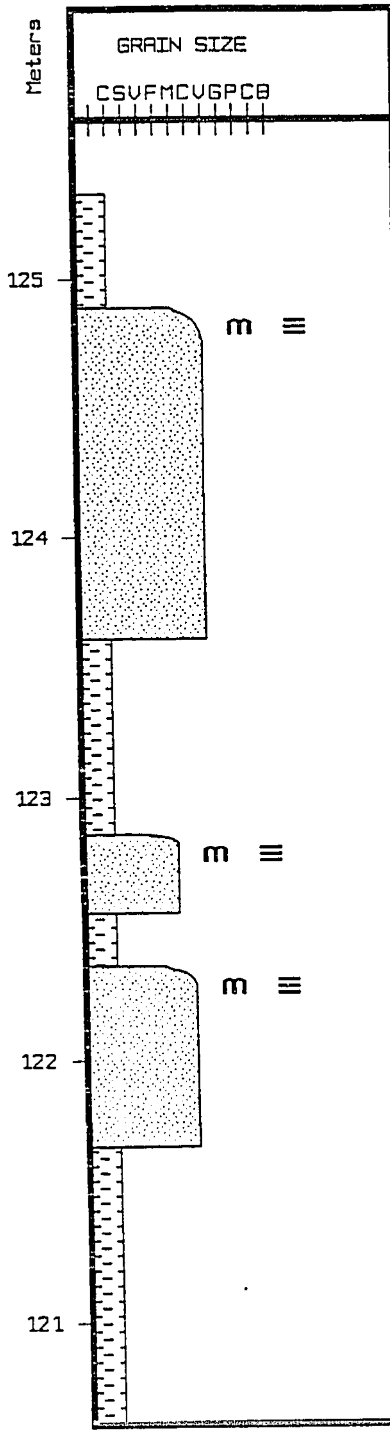
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

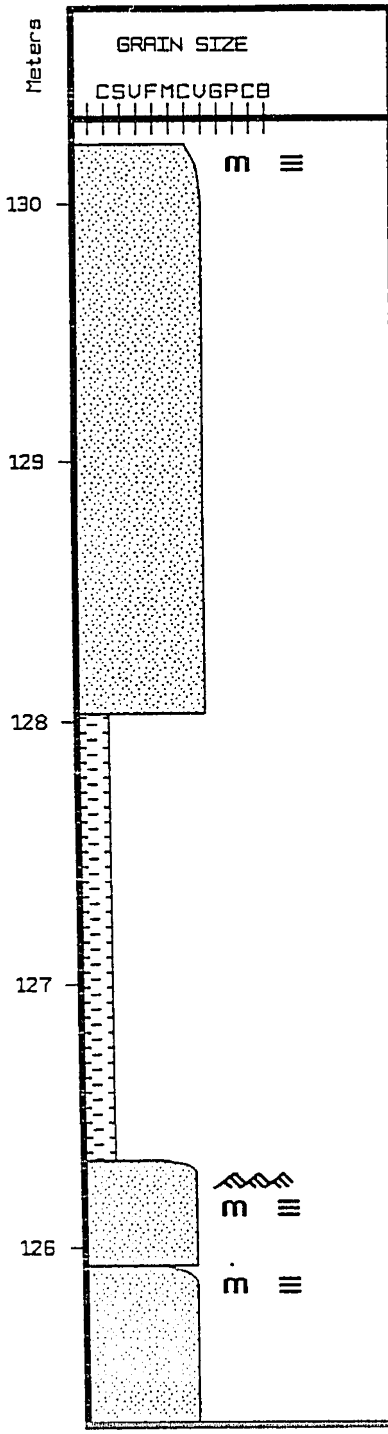
Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 4				Guinda Formation
	Shale	G	e	
	Ss, massive bedded, planar laminated	B	ab	
Channel 3	Shale	G	e	
	Ss, massive bedded, planar laminated	B	ab	
	Shale, poorly exposed	G	e	
	Ss, massive bedded, planar laminated	B	ab	
	Shale, sampe 90-DBS-42SH	G	e	

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 5	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 4	Shale, poorly exposed	G	e	
	Ss, massive bedded, planar laminated, ripple laminated	B	abc	
	Ss, massive bedded, planar laminated, shale at top	B	abe	

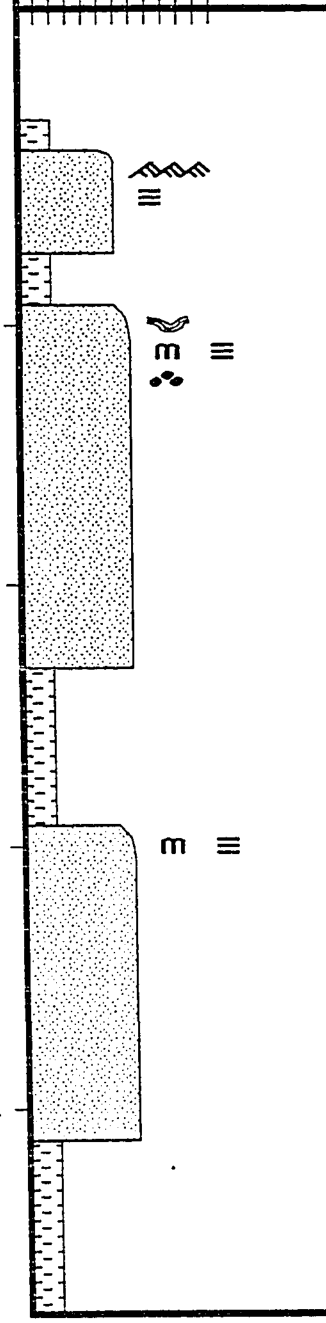
Alamo Creek/Gates Canyon

SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters: 131, 132, 133, 134

GRAIN SIZE: C S VF M C VG P C B



ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.
Shale	G	e
Ss, planar laminated, ripple laminated	D	bc
Shale	G	e
Ss, massive bedded, planar laminated, convolute laminated, shale rip-up clasts	B	abc
Shale, poorly exposed	G	e
Ss, massive bedded, planar laminated	B	ab
Shale	G	e

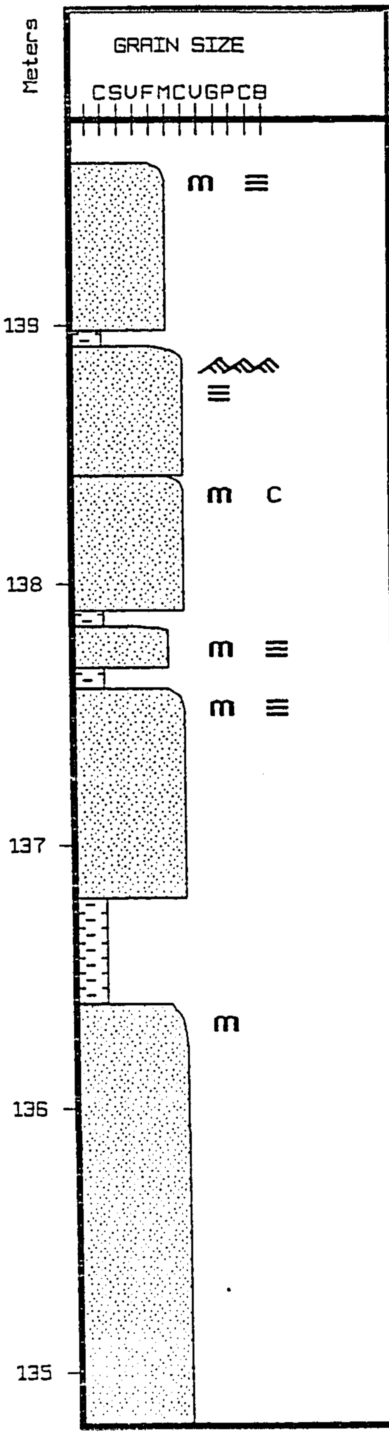
FACIES ASSOC.: Channel 5

FM.: Guinda Formation

Alamo Creek/Gates Canyon

SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

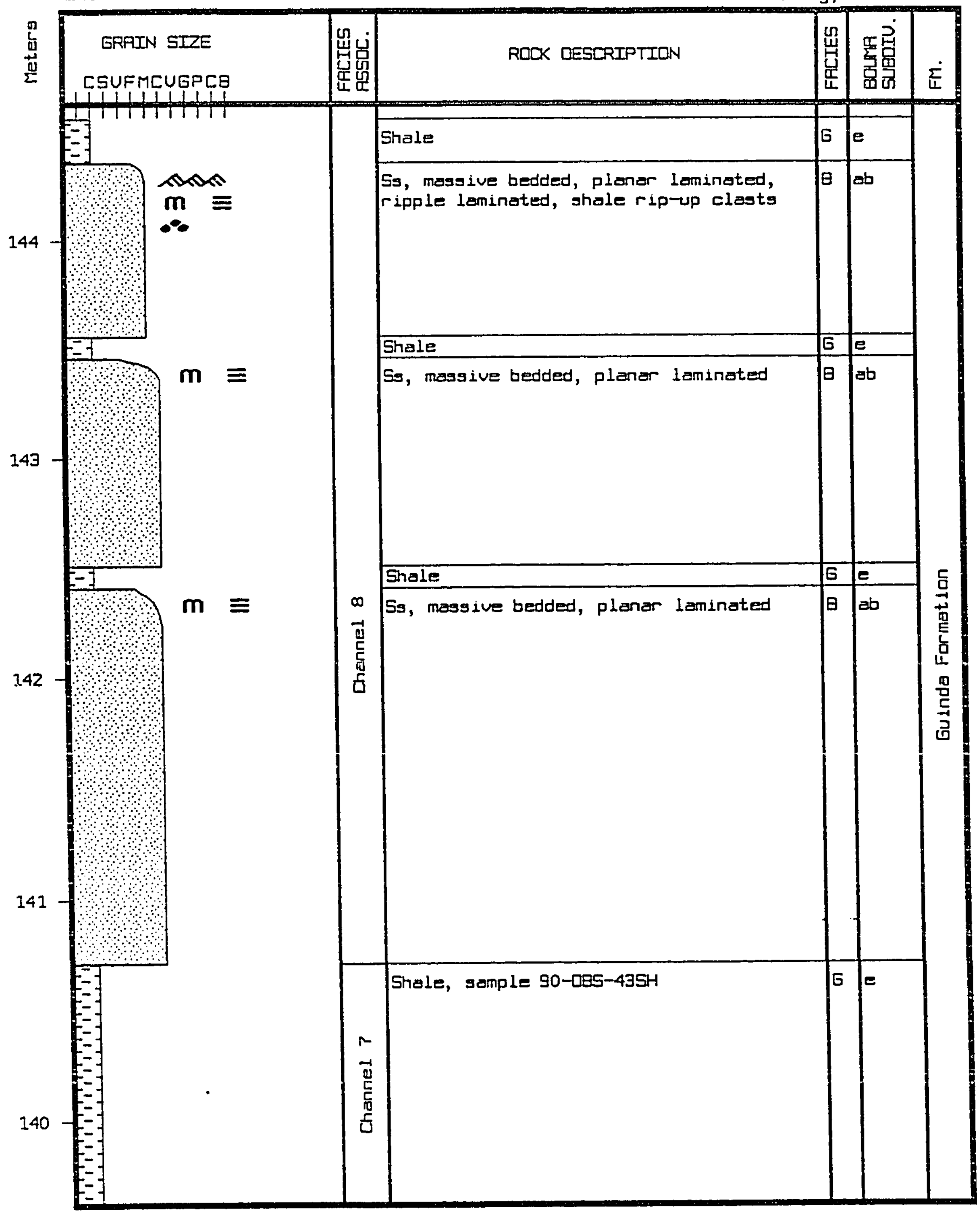


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 7	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 7	Shale, poorly exposed	G	e	Guinda Formation
Channel 7	Ss, planar laminated, ripple laminated, poorly exposed	B	bc	Guinda Formation
Channel 7	Ss, massive bedded, concretionary, shale at top	B	ae	Guinda Formation
Channel 7	Shale	G	e	Guinda Formation
Channel 6	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 6	Shale	G	e	Guinda Formation
Channel 6	Ss, massive bedded, planar laminated, poorly exposed	B	ab	Guinda Formation
Channel 6	Shale	G	e	Guinda Formation
Channel 6	Ss, massive bedded, poorly exposed	B	a	Guinda Formation

Alamo Creek/Gates Canyon

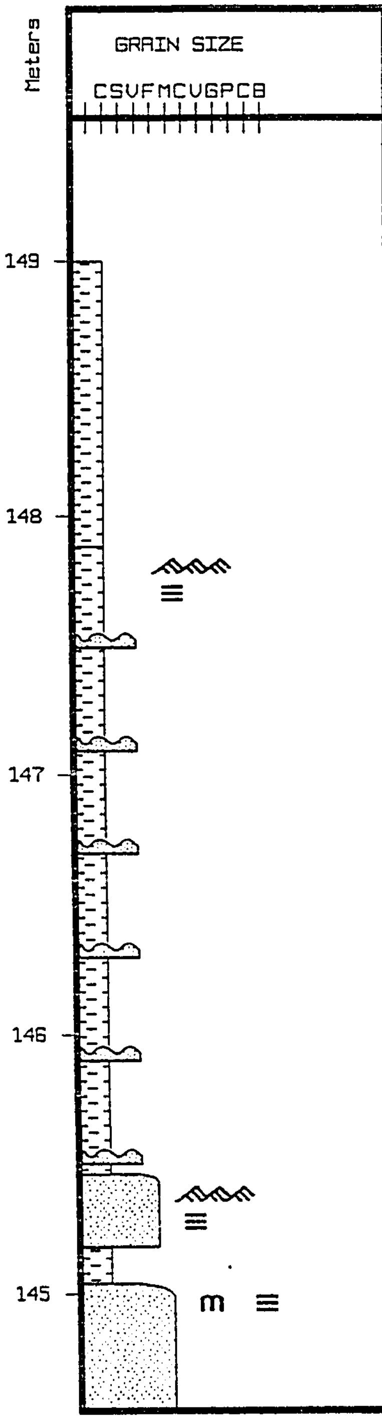
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

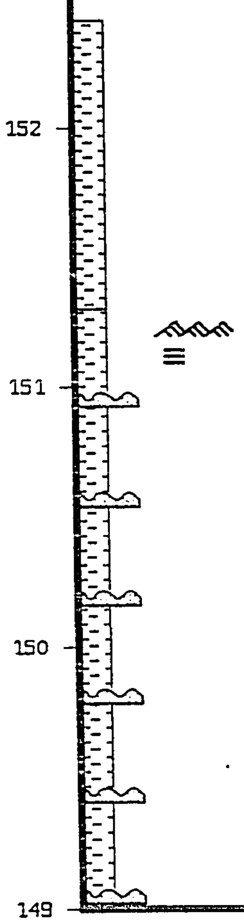
Solano County, California



Meters	Facies Assoc.	Rock Description	Facies	Bouma Subdiv.	Fm.
149–148	Interchannel	Shale	G	e	Guinda Formation
148–145.5	Interchannel	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation
	Channel 8	Ss, planar laminated, ripple laminated	D	bc	Guinda Formation
	Channel 8	Shale	G	e	Guinda Formation
145	Channel 8	Ss, massive bedded, planar laminated	B	ab	Guinda Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

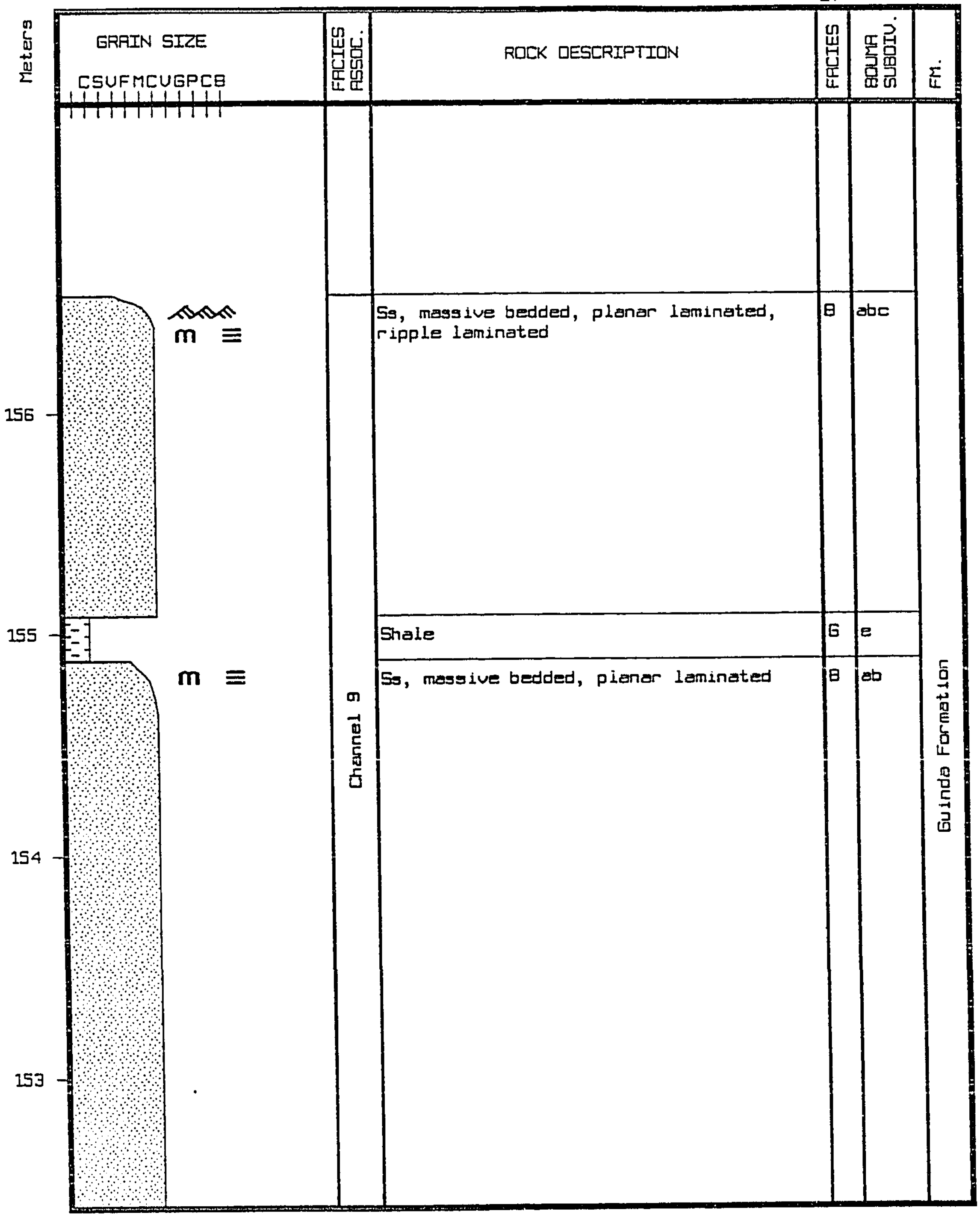
Solano County, California



Meters	GRAIN SIZE CSVFMCVGPCB	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
		Interchannel	Shale	G	e	Guinda Formation
		Interchannel	Interbedded shale and ss (ss:sh = 1:5), planar laminated, ripple laminated, max bed thickness=6 cm	DE G	bce	Guinda Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

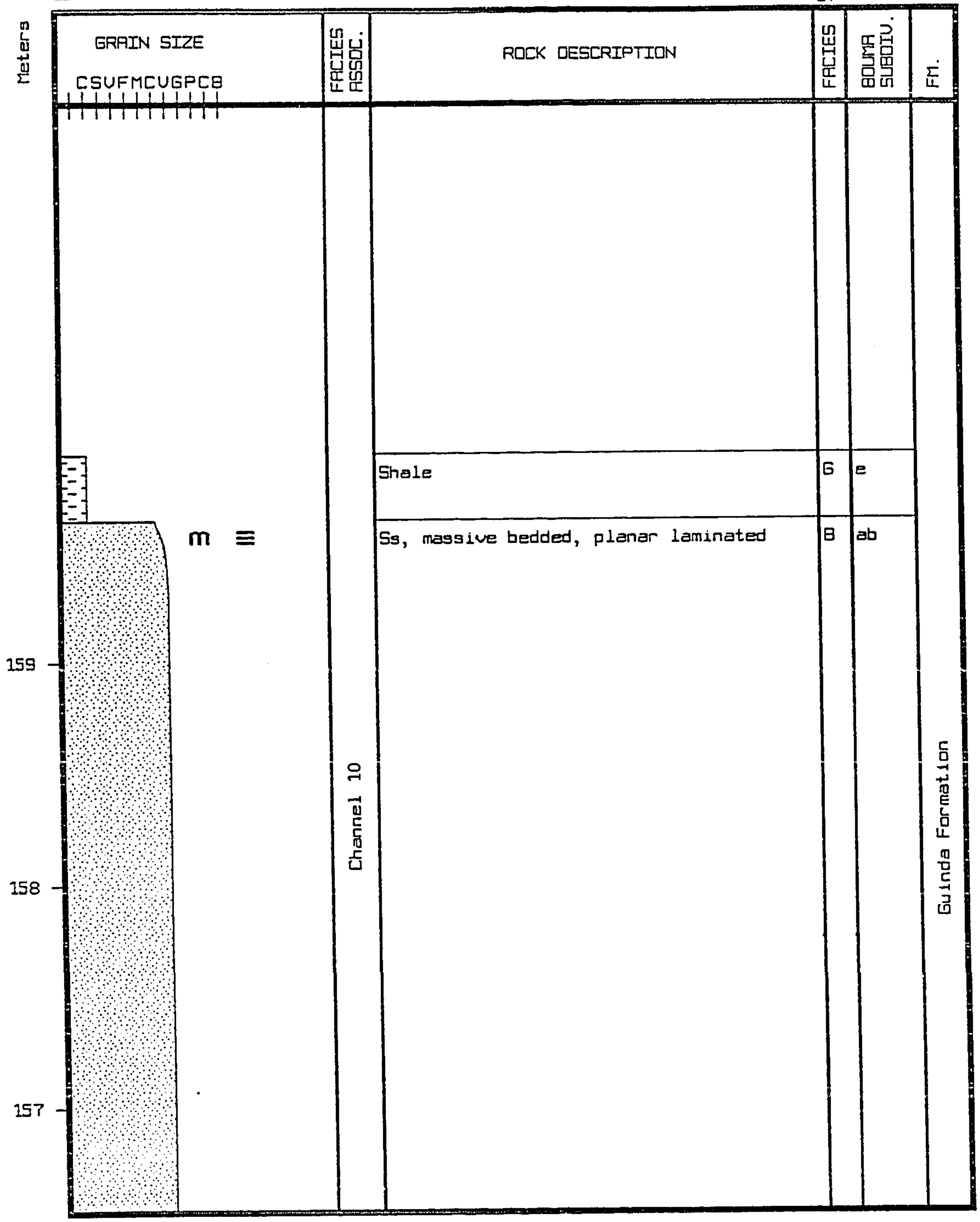
Solano County, California



Alamo Creek/Gates Canyon

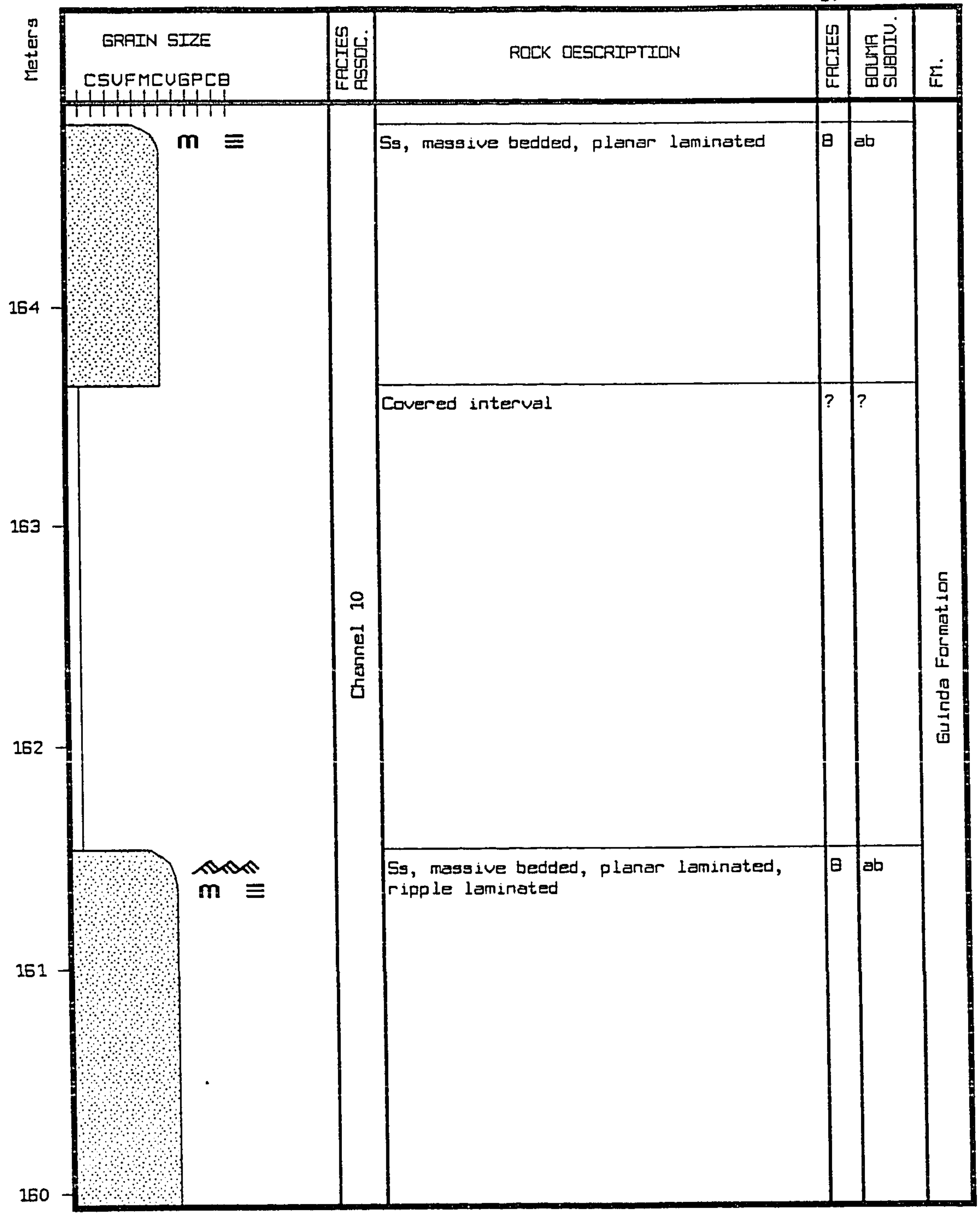
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



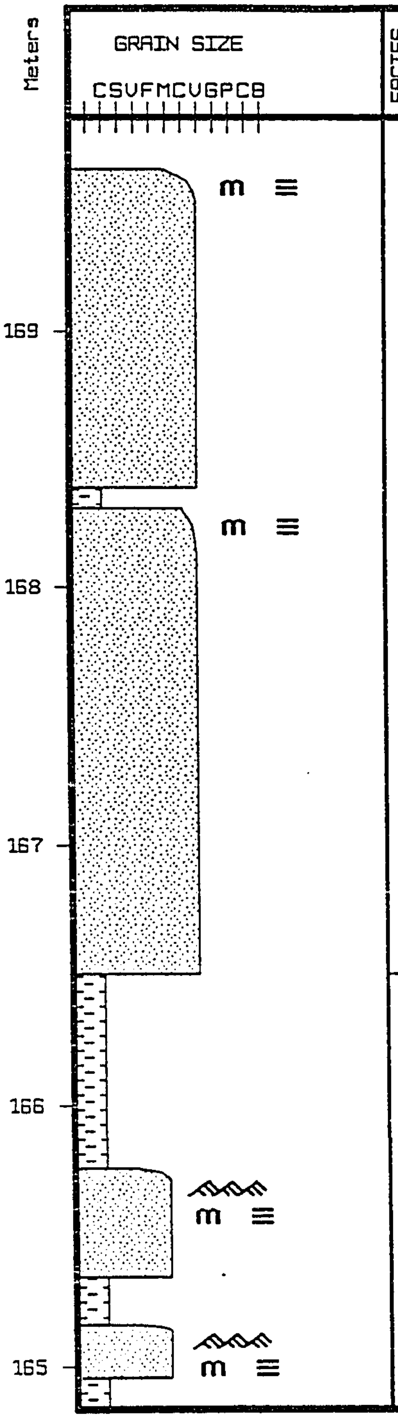
Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

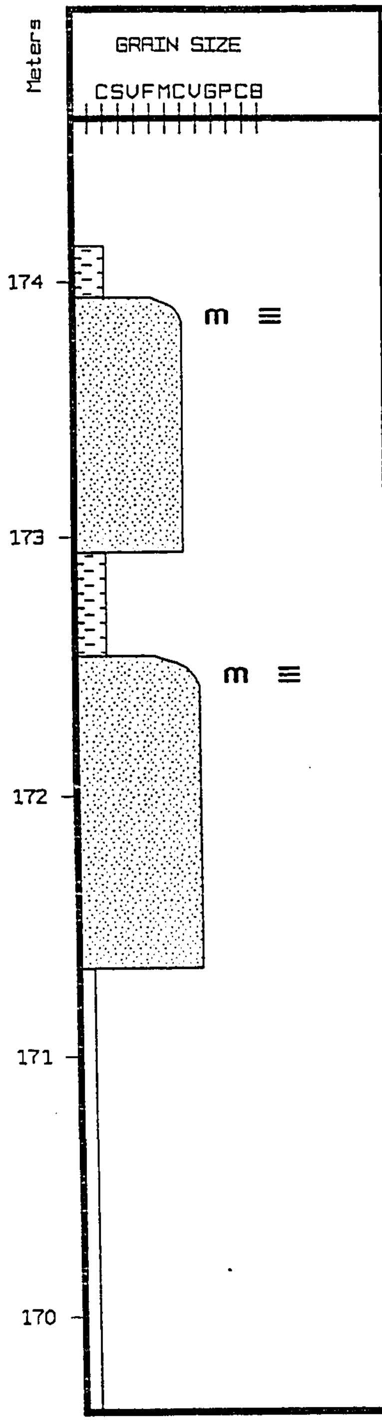
Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 11	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 11	Shale	G	e	Guinda Formation
Channel 11	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
Channel 10	Shale, poorly exposed	G	e	Guinda Formation
Channel 10	Ss, massive bedded, planar laminated, ripple laminated	B	abc	Guinda Formation
Channel 10	Shale	G	e	Guinda Formation
Channel 10	Ss, massive bedded, planar laminated, ripple laminated	B	ab	Guinda Formation
Channel 10	Shale	G	e	Guinda Formation

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Channel 11	Shale	G	e	Guinda Formation
	Ss, massive bedded, planar laminated	B	ab	
	Shale	G	e	
	Ss, massive bedded, planar laminated	B	ab	
	Covered interval	?	?	

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

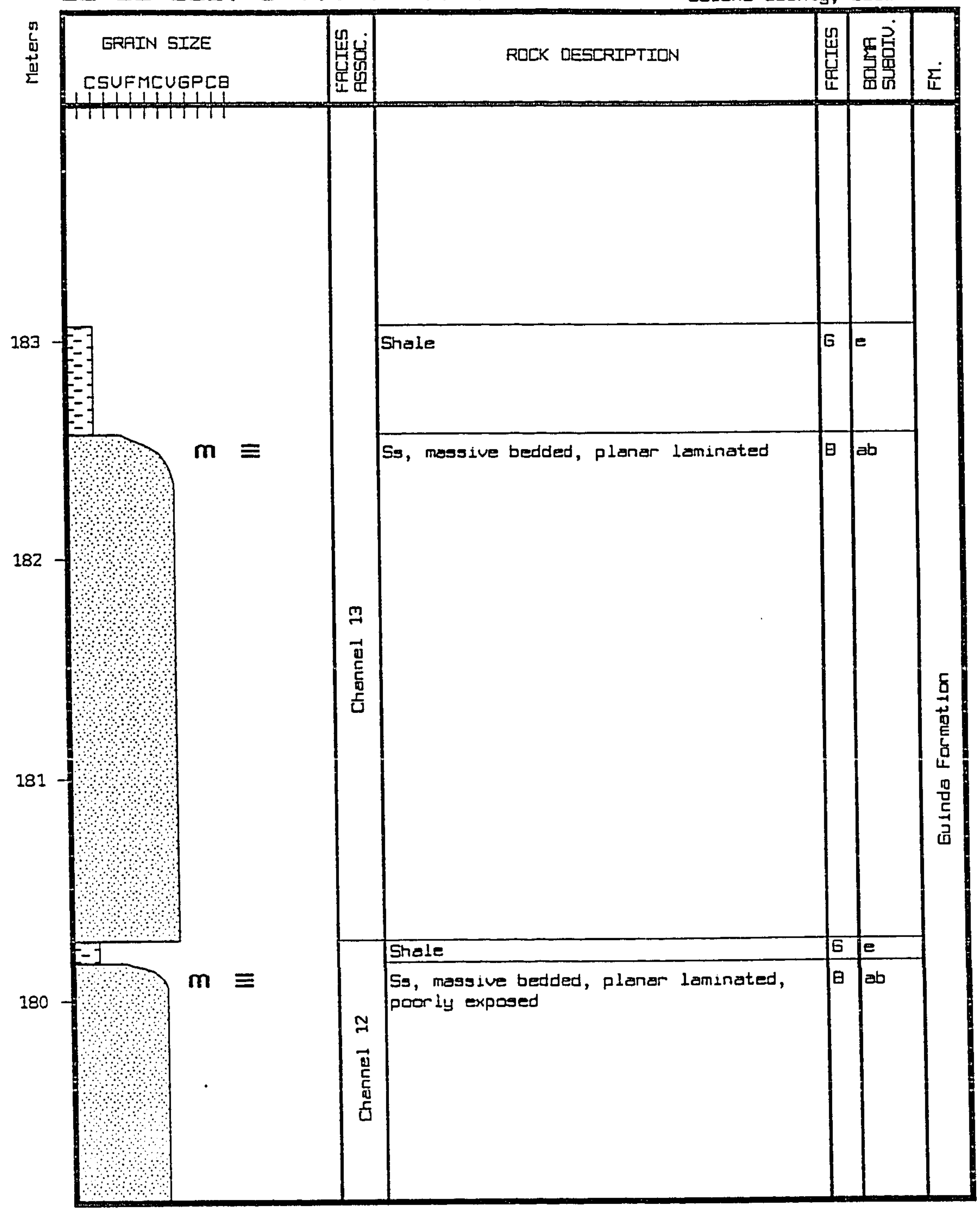
Solano County, California

Meters	GRAIN SIZE (C S VF F M C VC G P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
179		Channel 12	Shale	G	e	Guinda Formation
178, 177	m ≡	Channel 12	Ss, massive bedded, planar laminated	B	ab	Guinda Formation
176		Channel 11	Shale, sample 90-DBS-44SH	G	e	Guinda Formation
	m ≡	Channel 11	Ss, massive bedded, planar laminated, poorly exposed	B	ab	Guinda Formation
		Channel 11	Shale	G	e	Guinda Formation
175	m ≡	Channel 11	Ss, massive bedded, planar laminated	B	ab	Guinda Formation

Alamo Creek/Gates Canyon

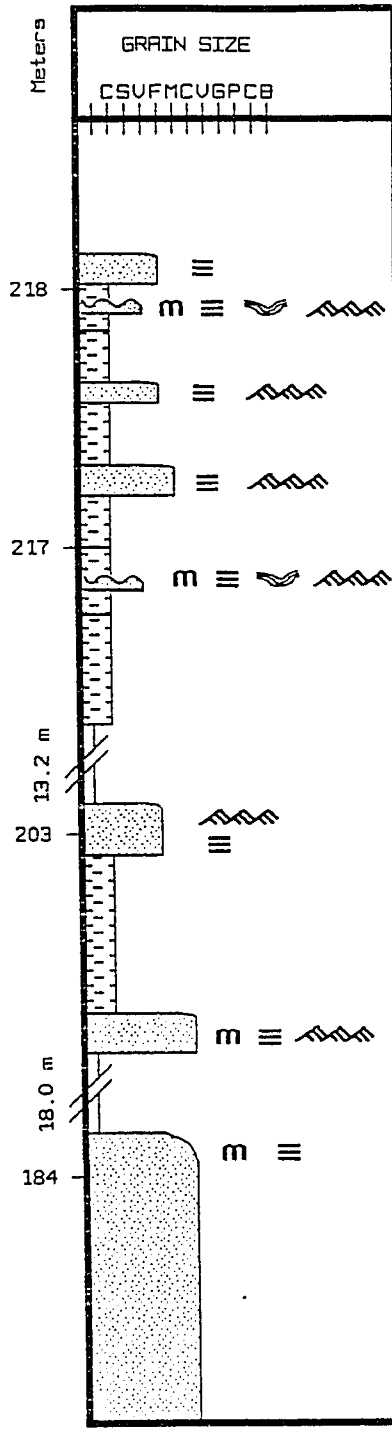
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California



Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

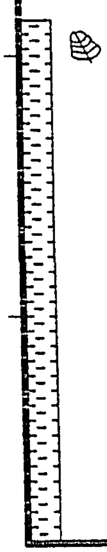
Solano County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Ss, planar laminated	D	b	Guinda Formation
Interchannel	Interbedded shale and ss (ss:sh = 1:5), massive bedded, planar laminated, ripple laminated, convolute laminated, max bed thickness=6 cm	DE G	abce	
	Shale	G	e	
	Ss, planar laminated, ripple laminated	D	b	
	Shale	G	e	
	Ss, planar laminated, ripple laminated, poorly exposed	D	b	
	Shale,	G	e	
	Interbedded shale and ss (ss:sh = 1:5), massive bedded, planar laminated, ripple laminated, convolute laminated, max bed thickness=6 cm	DE G	abce	
	Shale	G	e	
	Covered interval	?	?	
	Ss, planar laminated, ripple laminated, shale at top	DG	bce	
	Shale	G	e	
Crevasse Splay	Ss, massive bedded, planar laminated, ripple laminated	B	abc	
Inter-channel	Covered interval	?	?	
Channel 13	Ss, massive bedded, planar laminated, sample 90-DBS-32SS	B	ab	

Alamo Creek/Gates Canyon
SE SE Sec. 3 T.6N. R.2W. MDBM

Solano County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
220 219		Basin Plain	Shale, carbonaceous material/charcoal, poorly exposed, total thickness not measured, sample 90-DBS-45SH	6	e	Dobbins Shale Member

APPENDIX 2

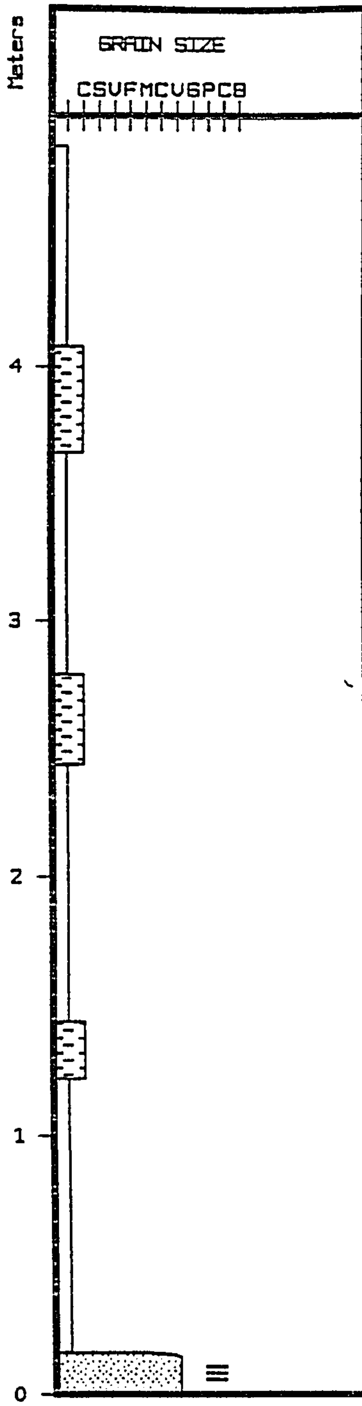
CORE DESCRIPTION

(Core description explanation same as
measured section explanation found in Appendix 1)

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

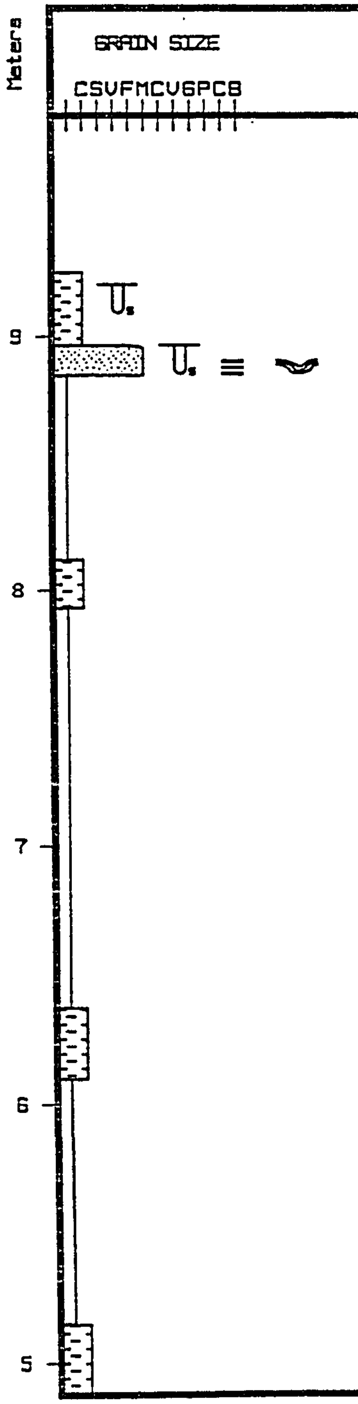
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Not present	?	?	Funka Formation
	Shale, recovered interval (ft): 438–442	?	e	
	Not present	?	?	
	Shale, recovered interval (ft): 442–446	?	e	
	Not present	?	?	
	Shale, recovered interval (ft): 448–452	?	e	
	Not present	?	?	
	Ss, planar laminated, recovered interval (ft): 452–456	?	b	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Shale, slightly burrowed, recovered interval (ft): 421-425	?	e	Funks Formation
	Ss, planar laminated, convolute laminated, slightly burrowed, recovered interval (ft): 421-425	?	bc	
	Not present	?	?	
	Shale, recovered interval (ft): 425-428, thin pyritized layers	?	e	
	Not present	?	?	
	Shale, recovered interval (ft): 428-432	?	e	
	Not present	?	?	
	Shale, recovered interval (ft): 432-438	?	e	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM Yolo County, California

Meters	GRAIN SIZE CSVFMCVGPCB	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
14		?	Shale, recovered interval (ft): 405–407	?	e	Funks Formation
			Not present	?	?	
13			Shale, recovered interval (ft): 407–411	?	e	
12			Not present	?	?	
			Shale, recovered interval (ft): 411–415	?	e	
11			Not present	?	?	
			Shale, recovered interval (ft): 417–421	?	e	
10			Not present	?	?	

Putah Creek Section C Diamond #1 Core — Page 4 of 25

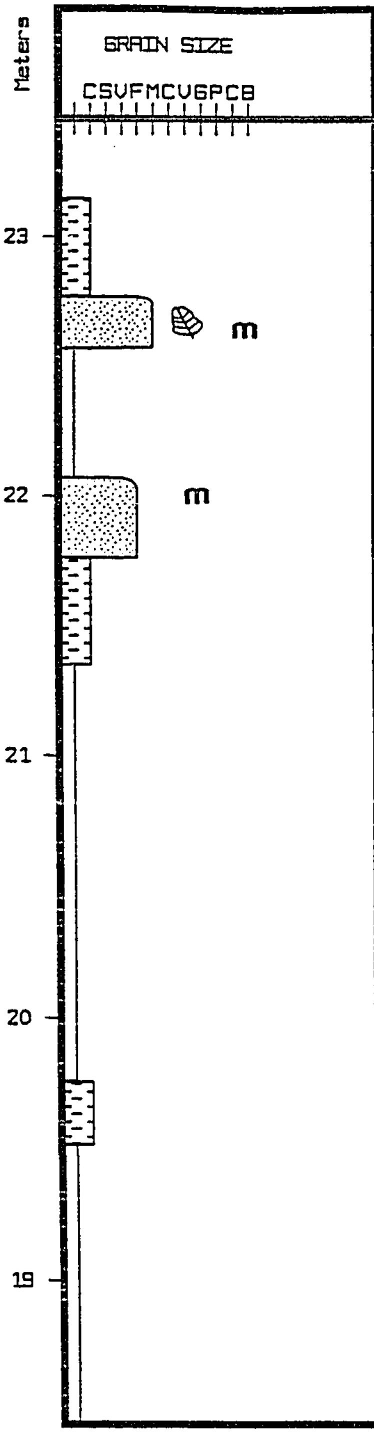
NW NW Sec. 27 T.8N. R.2W. MDBM — Yolo County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	m	?	Ss, massive bedded, convolute laminated, flame structure, recovered interval (ft): 385-389	?	ac	Funka Formation
18			Not present	?	?	
	m		Ss, massive bedded, convolute laminated, recovered interval (ft): 391-395	?	ac	
17			Not present	?	?	
	m ≡		Ss, massive bedded, planar laminated, recovered interval (ft): 395-399	?	ab	
16			Not present	?	?	
15			Shale, recovered interval (ft): 401-405	?	e	
			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Shale, recovered interval (ft): 371-375	?	e	Funks Formation
	Ss, massive bedded, carbonaceous material/charcoal, recovered interval (ft): 371-375	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 375-379	?	a	
	Shale, recovered interval (ft): 375-379	?	e	
	Not present	?	?	
	Shale, recovered interval (ft): 381-387, layers of shell hash	?	e	
	Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
28		?	Shale, recovered interval (ft): 351-355	?	e	Funks Formation
27			Not present	?	?	
			Shale, recovered interval (ft): 355-359	?	e	
26			Not present	?	?	
			Shale, recovered interval (ft): 361-365	?	e	
25			Not present	?	?	
24			Shale, recovered interval (ft): 365-369	?	e	
			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters: 32, 31, 30, 29

GRAIN SIZE: C S VF M C VG P C B

FACIES ASSOC.: ?

FM.: Funks Formation

ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.
Shale, recovered interval (ft): 332-336	?	e
Not present	?	?
Shale, recovered interval (ft): 336-340	?	e
Not present	?	?
Shale, recovered interval (ft): 340-343	?	e
Not present	?	?
Shale, recovered interval (ft): 343-346	?	e
Not present	?	?
Shale, recovered interval (ft): 346-349	?	e
Not present	?	?

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

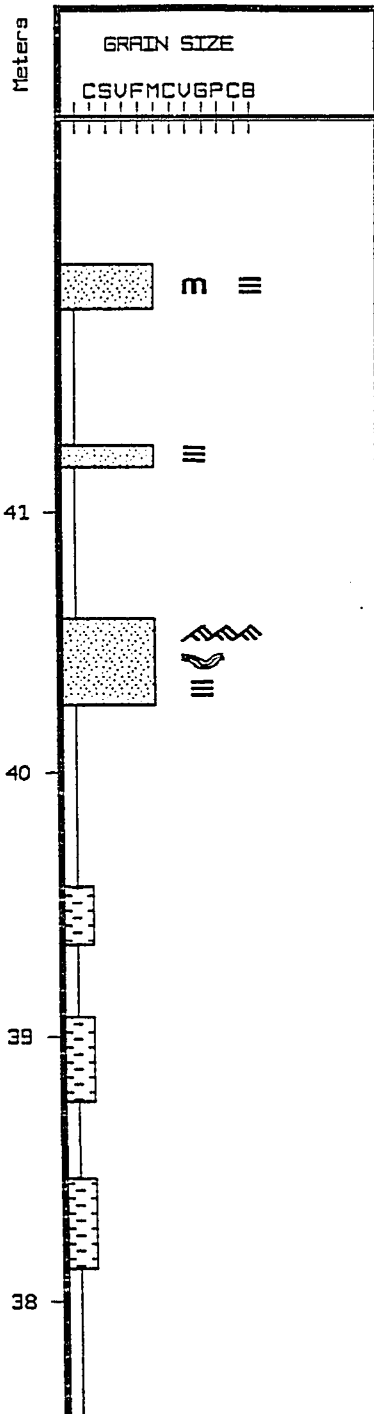
Yolo County, California

Meters	GRAIN SIZE C S VF M C VG P C B	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
		?	Shale, recovered interval (ft): 314-317	?	e	Funks Formation
37			Not present	?	?	
			Shale, recovered interval (ft): 317-320	?	e	
36			Not present	?	?	
			Shale, recovered interval (ft): 322-326	?	e	
35			Not present	?	?	
34			Shale, recovered interval (ft): 326-330	?	e	
33			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
				Guinda Formation
	Ss, massive bedded, planar laminated, recovered interval (ft): 297-300	?	a b	Guinda Formation
	Not present	?	?	Guinda Formation
	Ss, planar laminated, recovered interval (ft): 300-302	?	b	Guinda Formation
	Not present	?	?	Guinda Formation
	Ss, planar laminated, ripple laminated, convolute laminated, recovered interval (ft): 304-307, shale at top	?	bc	Guinda Formation
?	Not present	?	?	Funks Formation
	Shale, recovered interval (ft): 307-310	?	e	Funks Formation
	Not present	?	?	Funks Formation
	Shale, recovered interval (ft): 310-312	?	e	Funks Formation
	Not present	?	?	Funks Formation
	Shale, recovered interval (ft): 312-314	?	e	Funks Formation
	Not present	?	?	Funks Formation

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters	GRAIN SIZE CSVFMCVGPCB	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	m		Ss, massive bedded, recovered interval (ft): 282-284	?	a	Guinda Formation
			Not present	?	?	
46	m		Ss, massive bedded, recovered interval (ft): 284-287	?	a	
			Not present	?	?	
45	m		Ss, massive bedded, recovered interval (ft): 287-290	?	a	
			Not present	?	?	
	m	?	Ss, massive bedded, recovered interval (ft): 290-292	?	a	
			Not present	?	?	
44	m		Ss, massive bedded, recovered interval (ft): 292-394	?	a	
			Not present	?	?	
43	m		Ss, massive bedded, recovered interval (ft): 294-297	?	a	
42			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

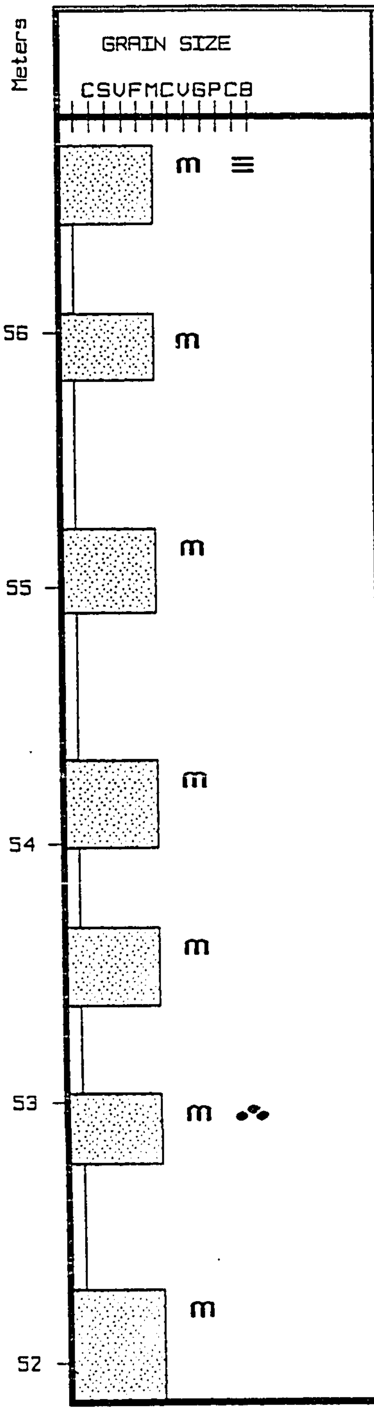
Yolo County, California

Meters	GRAIN SIZE (C S VF M C VC G P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
			Not present	?	?	
51	m		Ss, massive bedded, recovered interval (ft): 267-270	?	a	
			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 270-272	?	a	
50			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 272-274	?	a	Guinda Formation
		?	Not present	?	?	
49	m		Ss, massive bedded, recovered interval (ft): 274-277	?	a	
			Not present	?	?	
48	m		Ss, massive bedded, recovered interval (ft): 277-280	?	a	
			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 280-282	?	a	
47			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

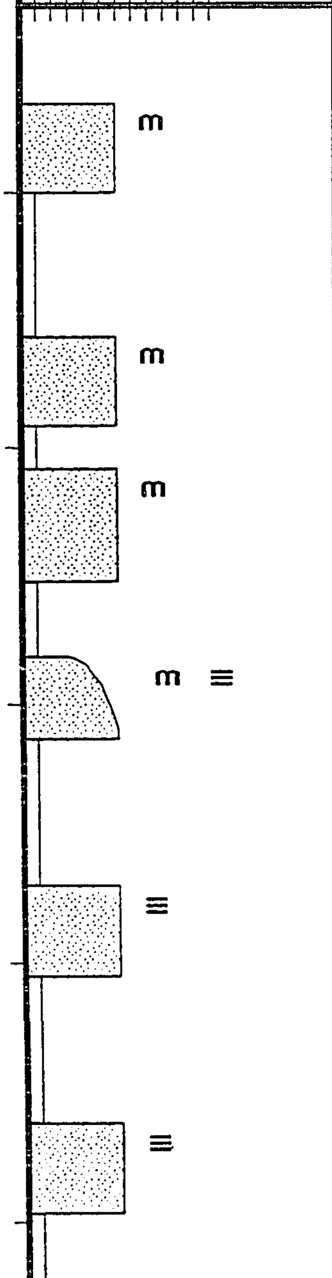
Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Ss, massive bedded, planar laminated, recovered interval (ft): 250-252	?	ab	Guinda Formation
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 252-254	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 254-257	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 257-260	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 260-262	?	a	
	Not present	?	?	
	Ss, massive bedded, shale rip-up clasts, recovered interval (ft): 262-264	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 264-267	?	a	

Putah Creek Section C Diamond #1 Core
NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

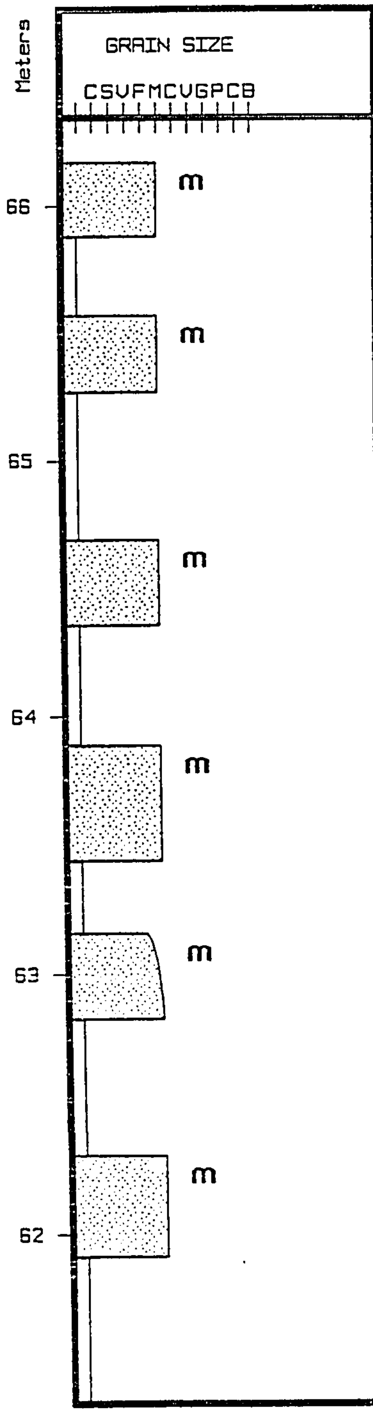


Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
						Guinda Formation
	m		Ss, massive bedded, recovered interval (ft): 234-237	?	a	
61			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 237-240	?	a	
60			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 240-242	?	a	
			Not present	?	?	
59	m ≡	?	Ss, massive bedded, planar laminated, recovered interval (ft): 242-244, shale at top	?	ab	
			Not present	?	?	
58	≡		Ss, planar laminated, recovered interval (ft): 244-247	?	b	
			Not present	?	?	
	≡		Ss, planar laminated, recovered interval (ft): 247-250	?	b	
57			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Ss, massive bedded, recovered interval (ft): 220-222	?	a	Guinda Formation
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 222-224	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 224-227	?	a	
	Not present	?	?	
?	Ss, massive bedded, recovered interval (ft): 227-230	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 230-232	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 232-234	?	a	
	Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters	GRAIN SIZE (C S VF F M C VC G P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
71			Not present	?	?	
70	m		Ss, massive bedded, recovered interval (ft): 205-210	?	a	
			Not present	?	?	
69	m		Ss, massive bedded, recovered interval (ft): 210-212	?	a	Guinda Formation
			Not present	?	?	
	m	?	Ss, massive bedded, recovered interval (ft): 212-214	?	a	
68			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 214-217, shale at top	?	ae	
67			Not present	?	?	
	m ≡		Ss, massive bedded, planar laminated, recovered interval (ft): 217-220, carbonaceous layers	?	abe	
			Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

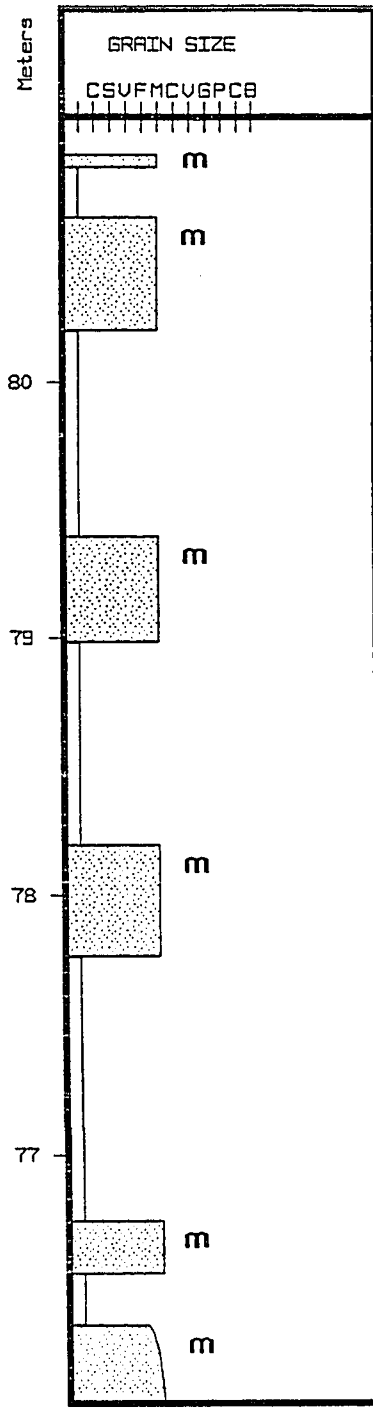
Yolo County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
76	≡	?	Ss, planar laminated, recovered interval (ft): 180-182	?	b	Guinda Formation
			Not present	?	?	
75	≡		Ss, planar laminated, recovered interval (ft): 182-186	?	b	
			Not present	?	?	
	m ≡		Ss, massive bedded, planar laminated, recovered interval (ft): 190-192	?	ab	
74			Not present	?	?	
	≡		Ss, planar laminated, recovered interval (ft): 192-194	?	b	
			Not present	?	?	
73	≡		Ss, planar laminated, recovered interval (ft): 197-200	?	b	
72			Not present	?	?	
	m		Ss, massive bedded, recovered interval (ft): 200-205	?	a	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Ss, massive bedded, recovered interval (ft): 162-166	?	a	Guinda Formation
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 166-170	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 170-172, shale at top	?	ae	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 172-176	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 176-180	?	a	
	Not present	?	?	
	Ss, massive bedded, recovered interval (ft): 180-182	?	a	

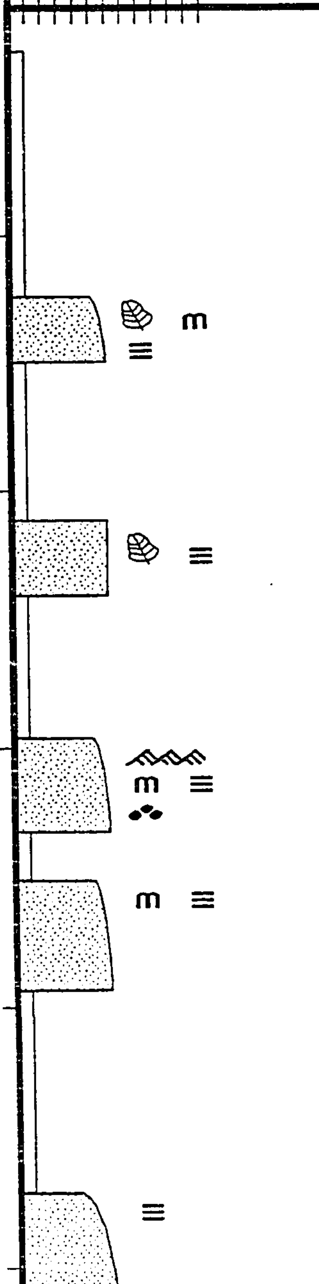
Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters: 85, 84, 83, 82, 81

GRAIN SIZE
CSVFMCVGPCB



ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
Not present	?	?	Guinda Formation
Ss, massive bedded, planar laminated, carbonaceous material/charcoal, recovered interval (ft): 152-154	?	abe	
Not present	?	?	
Ss, planar laminated, carbonaceous material/charcoal, recovered interval (ft): 154-157	?	be	
Not present	?	?	
Ss, massive bedded, planar laminated, ripple laminated, shale rip-up clasts, recovered interval (ft): 157-160	?	abc	
Not present	?	?	
Ss, massive bedded, planar laminated, recovered interval (ft): 160-162	?	ab	
Not present	?	?	
Ss, planar laminated, recovered interval (ft): 162-166	?	b	

Putah Creek Section C Diamond #1 Core
NW NW Sec. 27 T.8N. R.2W. MDBM

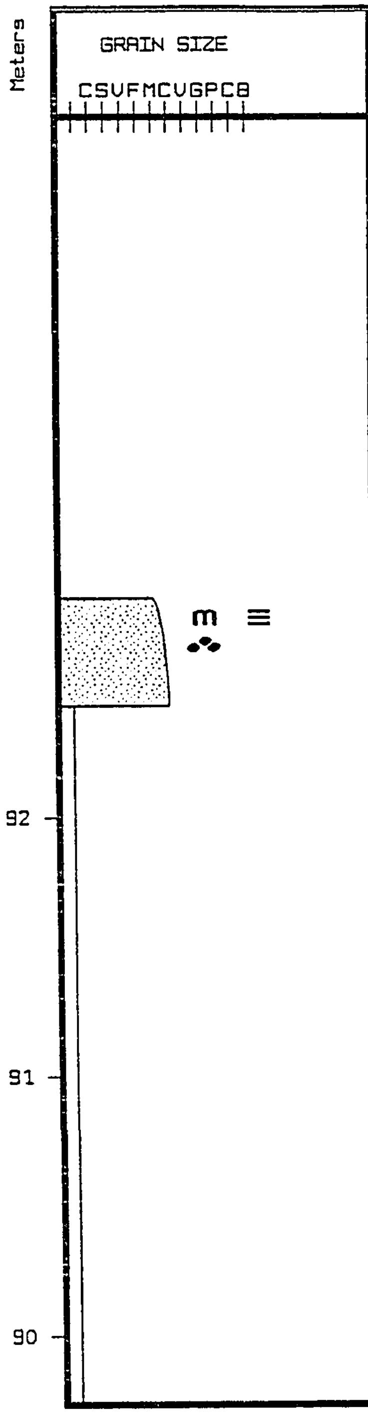
Yolo County, California

Meters	GRAIN SIZE (C S VF F M C VC G P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	m		Ss, massive bedded, recovered interval (ft): 160-140	?	a	
			Not present	?	?	
89						
	m		Ss, massive bedded, recovered interval (ft): 140-143	?	a	
			Not present	?	?	
88						
	m		Ss, massive bedded, shale rip-up clasts, recovered interval (ft): 143-146	?	a	Guinda Formation
		?	Not present	?	?	
87						
	m		Ss, massive bedded, recovered interval (ft): 146-150	?	a	
			Not present	?	?	
86						
	m		Ss, massive bedded, recovered interval (ft): 150-152	?	a	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



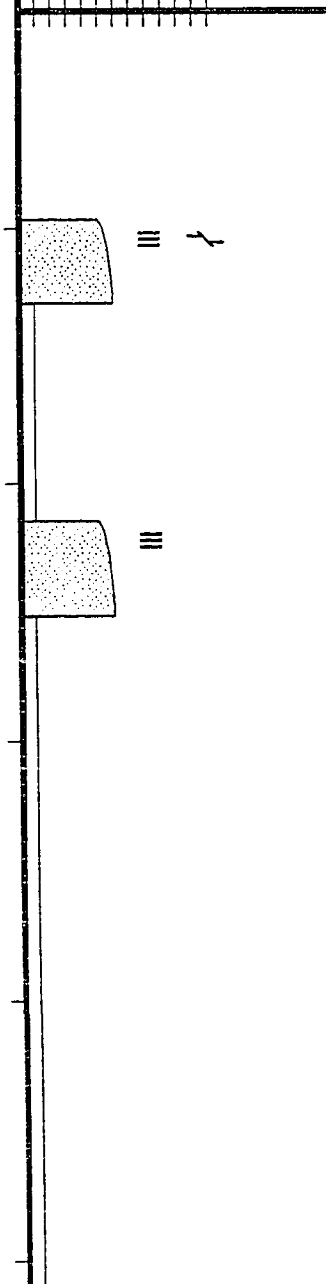
FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
?	Ss, massive bedded, planar laminated, shale rip-up clasts, recovered interval (ft): 120-130	?	ab	Guinda Formation
	Not present	?	?	

Putah Creek Section C Diamond #1 Core
NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

GRAIN SIZE

CSVFMCVGPCB

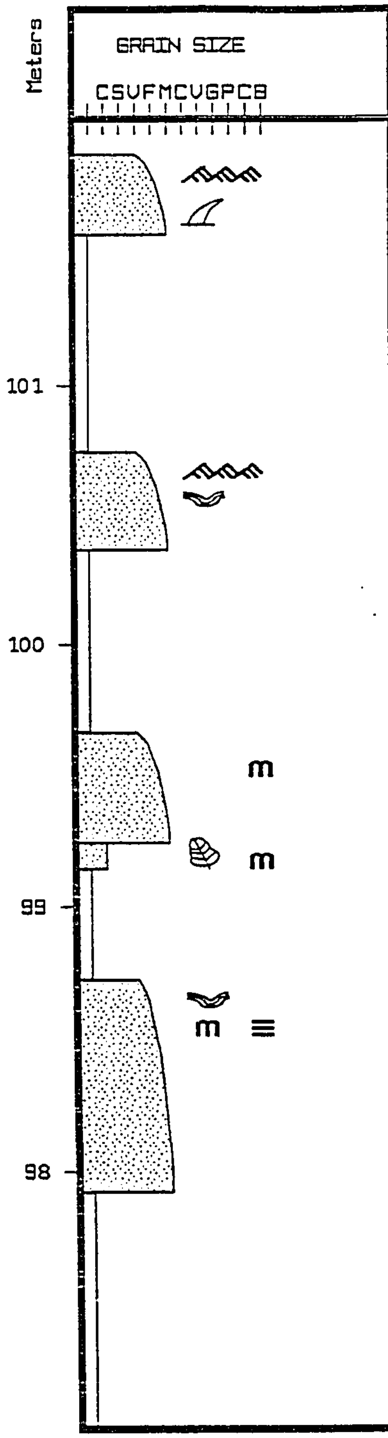


Meters	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
97	?	Ss, planar laminated, faulted, recovered interval (ft): 112-116	?	b	Guinda Formation
		Not present	?	?	
96		Ss, planar laminated, recovered interval (ft): 116-120	?	b	
95		Not present	?	?	
94					
93					

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

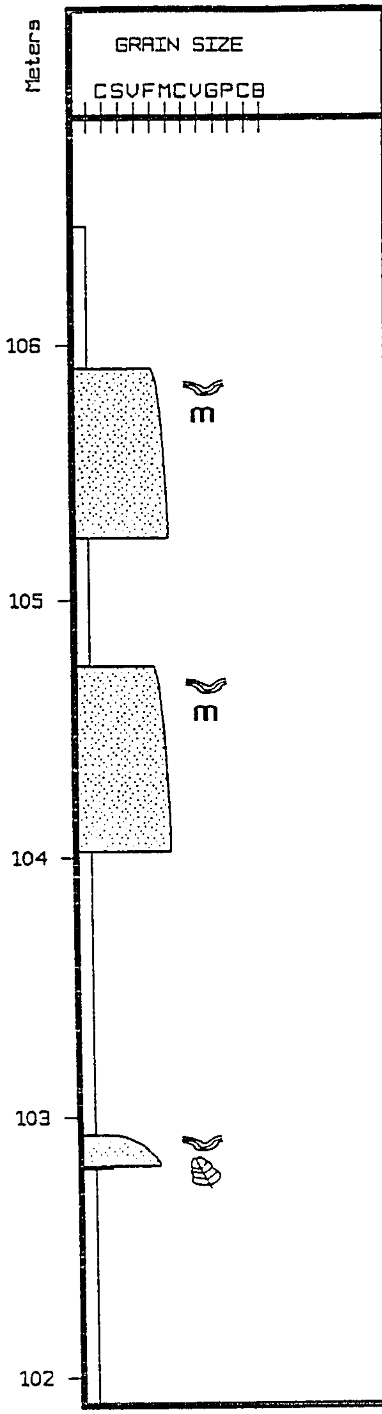


FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	Ss, ripple laminated, flame structure, recovered interval (ft): 96-100	?	c	Guinda Formation
	Not present	?	?	
	Ss, ripple laminated, convolute laminated, recovered interval (ft): 96-100	?	c	
	Not present	?	?	
?	Ss, massive bedded, recovered interval (ft): 102-106	?	a	
	Ss, massive bedded, carbonaceous material/charcoal, recovered interval (ft): 102-106	?	ae	
	Not present	?	?	
	Ss, massive bedded, planar laminated, convolute laminated, recovered interval (ft): 106-110	?	ab	
	Not present	?	?	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California



FACIES ASSOC.: ?

ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.
Not present	?	?
Ss, massive bedded, convolute laminated, recovered interval (ft): 82-86	?	abc
Not present	?	?
Ss, massive bedded, convolute laminated, recovered interval (ft): 86-90	?	abc
Not present	?	?
Ss, convolute laminated, recovered interval (ft): 92-96	?	c
Shale, carbonaceous material/charcoal, recovered interval (ft): 92-96	?	e
Not present	?	?

FM.: Guinda Formation

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters	GRAIN SIZE (C S VF M C VG P C B)	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
	m		Ss, massive bedded, recovered interval (ft): 60-65	?	a	
110			Not present	?	?	
109	m		Ss, massive bedded, recovered interval (ft): 65-70	?	a	
		?	Not present	?	?	Guinda Formation
108	m ≡		Ss, massive bedded, planar laminated, convolute laminated, recovered interval (ft): 72-76	?	abc	
			Not present	?	?	
107	m ≡		Ss, massive bedded, planar laminated, convolute laminated, recovered interval (ft): 76-80	?	abc	

Putah Creek Section C Diamond #1 Core

NW NW Sec. 27 T.8N. R.2W. MDBM

Yolo County, California

Meters	GRAIN SIZE C S VF M C VG P C B	FACIES ASSOC.	ROCK DESCRIPTION	FACIES	BOUMA SUBDIV.	FM.
		?	Not present	?	?	Guinda Formation
111						

APPENDIX 3

RESULTS OF STUDY OF MICROPALEONTOLOGIC SAMPLES

MICROPALEONTOLOGICAL SAMPLES

(Faunal data provided by
UNOCAL, Corp., Ventura, California)

Note: Abbreviations after faunal name refers to specimen recovery for that sample. The following abbreviations are used:

VR = Very Rare (1 specimen)
R = Rare (2-4 specimens)
C = Common (5-30 specimens)
A = Abundant (more than 30 specimens)

SAMPLE 89-DBS-02SH

LOCATION	:	Black Butte Reservoir, SE SE sec. 31, T.23N, R.4W
STRATIGRAPHIC LOCATION	:	lower Guinda Formation
FAUNA	:	*Haplophragmoides* sp. (VR), *Cribrostomoides cretacea* (R)
AGE	:	Late Cretaceous, E zone or older
SAMPLE LITHOLOGY	:	claystone
PALEOBATHYMETRY	:	bathyal

SAMPLE 89-DBS-03SH

LOCATION	:	Black Butte Reservoir, NE SE sec. 31, T.23N, R.4W
STRATIGRAPHIC LOCATION	:	upper Guinda Formation
FAUNA	:	radiolarians (A), megafossil fragments (C) *Inoceramus* prisms (C) *Lenticulina* sp. (C) *Gaudryina pyramidata* (C) *Bathysiphon* sp. (R) *Nodosaria* sp. (R)

		Dorothia oxycona (R) _Bermudezina uvigerinaformis_ (VR) _Nuttallinella florealis_ (VR) _Cribrostomoides cretacea_ (C) _Planulina spissocostata_ (VR) _Eponides bandyi_ (VR) _Silicosigmoilina californica_ (VR) _Haplophragmoides_ sp. (R) _Globotruncana lapparenti_ (VR) _Globotruncana bulloides_ (VR)
AGE	:	upper Santonian to Campanian, G-1 zone of Goudkoff (1945).
SAMPLE LITHOLOGY	:	fine sandstone
PALEOBATHYMETRY	:	middle to lower bathyal

SAMPLE 90-DBS-24SH

LOCATION	:	Black Butte Reservoir, NE SE sec. 31, T.23N, R.4W
STRATIGRAPHIC LOCATION	:	lower Dobbins Shale Member of the Forbes Formation
FAUNA	:	radiolarians (R) _Bathysiphon_ sp. (R) _Bermudezina uvigerinaformis_ (R) _Cribrostomoides cretacea_ (C) _Haplophragmoides_ sp. (R) _Silicosigmoilina californica_ (R)
AGE	:	Late Cretaceous (G-2 zone or younger)
SAMPLE LITHOLOGY	:	siltstone
PALEOBATHYMETRY	:	middle to lower bathyal

SAMPLE 90-DBS-20SH

LOCATION	:	South Fork Willow Creek, SE NW sec. 9, T.19N, R.4W
STRATIGRAPHIC LOCATION	:	upper Funks Formation

FAUNA : _Bathysiphon_ sp. (R)
Cribrostomoides _cretacea_ (R)
Psammosphaera _laevigata_ (VR)

AGE : Late Cretaceous E to G-2 zone

SAMPLE LITHOLOGY : well-cemented fine sandstone

PALEOBATHYMETRY : bathyal

SAMPLE 90-DBS-27SH

LOCATION : South Fork Willow Creek, NE SE sec. 9, T.19N, R.4W

STRATIGRAPHIC LOCATION: lower Dobbins Shale Member of the Forbes Formation

FAUNA : radiolarians (VR)
Cribrostomoides _cretacea_ (R)
Bermudezina _uvigerinaformis_ (VR)
Bathysiphon sp. (R)

AGE : Late Cretaceous F-2 to G-2 zone

SAMPLE LITHOLOGY : claystone

PALEOBATHYMETRY : bathyal

SAMPLE 90-DBS-34SH

LOCATION : Salt Creek, Capay Hills, SE SE sec. 33, T.13N, R.3W

STRATIGRAPHIC LOCATION: lower Guinda Formation

FAUNA : _Inoceramus_ prisms (R)
Lenticulina sp. (R)
Gaudryina _pyramidata_ (R)
Bathysiphon sp. (C)
Silicosigmoilina _californica_ (C)
Gaudryina _pyramidata_ (R)
Cribrostomoides _cretacea_ (C)
Bermudezina _uvigerinaformis_ (R)

AGE : Late Cretaceous G-1 or G-2 zone

SAMPLE LITHOLOGY : claystone

PALEOBATHYMETRY : middle to lower bathyal

SAMPLE 90-DBS-37SH

LOCATION : Salt Creek, Capay Hills, SW SE sec. 34, T.13N, R.3W

STRATIGRAPHIC LOCATION: lower Dobbins Shale Member of the Forbes Formation

FAUNA : pyrite (C)
Inoceramus prisms (R)
megafossil fragments (C)
pyritized radiolarians
Cibicides harperi (VR)
Globotruncana sp. (VR)
Lenticulina (R)
Bathysiphon sp. (R)
Psammosphaera laevigata (R)
Haplophragmoides sp. (C)

AGE : Late Cretaceous E zone or older

SAMPLE LITHOLOGY : fine, well-cemented sandstone with common rock fragments

PALEOBATHYMETRY : bathyal

SAMPLE 90-DBS-46SH

LOCATION : Bray Canyon, Putah Creek, SE SE sec. 21, T. 8N, R.2W

STRATIGRAPHIC LOCATION: lower Guinda Formation

FAUNA : pyrite (R)
Haplophragmoides sp. (C)
Dorothia oxycona (R)
Bathysiphon sp. (VR)
Cibicides constricta (R)
Lenticulina sp. (C)
Eponides bandyi (C)
Nuttalinella florealis (R)
Stensiöina exsculpta (VR)
Aragonia sp. (C)

		<u>Archeoglobigerina</u> <u>bosquensis</u> (C) <u>Globotruncana</u> <u>bulloides</u> (C) <u>Globotruncana</u> <u>lapparenti</u> (R) <u>Globigerinelloides</u> <u>ultramicra</u> (VR)
AGE	:	benthic : F-2 or G-1 zone planktonic: uppermost Santonian <u>Dicarinella</u> <u>asymetrica</u> zone of Caron, 1989)
SAMPLE LITHOLOGY	:	siltstone with common shell fragments
PALEOBATHYMETRY	:	middle to lower bathyal

<u>SAMPLE 90-DBS-40SH</u>

LOCATION	:	Bray Canyon, Putah Creek, SW SW sec. 22, T. 8N, R.2W
STRATIGRAPHIC LOCATION	:	upper Guinda Formation
FAUNA	:	<u>Bathysiphon</u> sp. (R) <u>Haplophragmoides</u>? sp. (VR)
AGE	:	indeterminate
SAMPLE LITHOLOGY	:	siltstone
PALEOBATHYMETRY	:	bathyal?

<u>SAMPLE 90-DBS-17SH</u>

LOCATION	:	Ulatis Creek, Mix Canyon, NW SW sec. 34, T. 7N, R.2W
STRATIGRAPHIC LOCATION	:	lower Guinda Formation
FAUNA	:	barren
AGE	:	indeterminate
SAMPLE LITHOLOGY	:	claystone
PALEOBATHYMETRY	:	indeterminate

SAMPLE 90-DBS-16SH

LOCATION	:	Ulatis Creek, Mix Canyon, NW SW sec. 34, T. 7N, R.2W
STRATIGRAPHIC LOCATION:		upper Guinda Formation
FAUNA	:	barren
AGE	:	indeterminate
SAMPLE LITHOLOGY	:	claystone
PALEOBATHYMETRY	:	bathyal

SAMPLE 90-DBS-43SH

LOCATION	:	Alamo Creek, Gates Canyon, SE SE sec. 3, T. 6N, R.2W
STRATIGRAPHIC LOCATION:		middle-to-upper Guinda Formation
FAUNA	:	*Bathysiphon* sp. (C) *Haplophragmoides cretacea* (R)
AGE	:	Cretaceous undifferentiated
SAMPLE LITHOLOGY	:	siltstone
PALEOBATHYMETRY	:	bathyal?

SAMPLE 90-DBS-44SH

LOCATION	:	Alamo Creek, Gates Canyon, SE SE sec. 3, T. 6N, R.2W
STRATIGRAPHIC LOCATION:		upper Guinda Formation
FAUNA	:	*Bathysiphon* sp. (VR)
AGE	:	indeterminate
SAMPLE LITHOLOGY	:	siltstone
PALEOBATHYMETRY	:	marine

SAMPLE 90-DBS-45SH

LOCATION	:	Alamo Creek, Gates Canyon, SE SE sec. 3, T. 6N, R.2W
STRATIGRAPHIC LOCATION	:	lower Dobbins Shale Member of the Forbes Formation
FAUNA	:	barren
AGE	:	indeterminate
SAMPLE LITHOLOGY	:	siltstone
PALEOBATHYMETRY	:	indeterminate